M.O. 590 AIR MINISTRY

METEOROLOGICAL OFFICE

THE METEOROLOGICAL MAGAZINE

VOL. 84, No. 994, APRIL 1955

SUMMER OF 1954

Colloquium at the Meteorological Office, Harrow

The summer of 1954 was dull, wet and cool in many parts of the British Isles. To say how bad or unusual it really was must await the analysis of full climatological returns; nevertheless there was thought to be some advantage in having a preliminary discussion while memories of it were still fresh. Accordingly an informal meeting was held at the Meteorological Office, Harrow on October 29, 1954. It was attended by some 70 members of the Victory House, Harrow and Dunstable staff; Professor Gordon Manley and Mr. C. K. M. Douglas were present by invitation. The meeting took the form of a colloquium with the opening speakers representing British and world climatology, forecasting research, upper air climatology and marine climatology.

Openers' contributions.—*Dr. J. Glasspoole*, Head of the British Climatology Branch, described, in broad outline, weather for the United Kingdom as a whole for the three months, June, July and August 1954. The most striking departures from average occurred over England and Wales where the general rainfall was 3·1 in. more than the 1881–1915 average, the mean temperature 2·5°F. below, and the mean daily sunshine 1·7 hr. below the 1921–50 average.

Over England and Wales there were six wetter summers in the last 54 yr.; the two wettest were in 1912 and 1879 with 15·9 and 15·7 in. respectively, well above the total of 11·8 in. recorded in 1954. Nor was the frequency of rain-days during the past summer outstanding, seeing that since 1917 the summers of 1946 and 1927 had more rain-days, and 1946, 1927 and 1924 more wet-days; at representative stations for the summer of 1954 the mean numbers were 53 rain-days and 40 wet-days (out of 92 days).

The mean temperature of the summer was about equal to the normal temperature of June. This low value was due more especially to lower maximum than to lower minimum temperatures. Of the last 53 summers only two, 1922 and 1907, were cooler over England and Wales.

The mean sunshine recorded during the three summer months this year was less than that recorded in April, May or September. Indeed it was less than that normally expected in April or September in spite of the shorter days of these two months. The only summer with less sunshine since 1906 was in 1912 which was also a wet summer.

Cole Memorial Library

Dr. Glasspoole showed diagrams of running 10-yr. means in order to bring out the long-term weather trends. These suggest that the recent wet, cool and dull summer continues a trend which has already been in evidence for some years past.

Dr. J. Pepper, Head of the World Climatology Branch, described the features of this summer's weather in some other parts of the world, illustrating his remarks by the monthly charts of rainfall, pressure and temperature and their anomalies, constructed from the broadcast CLIMAT data. In Europe the summer was, in general, cooler and rainier than normal though for the individual months it was warmer or drier than normal in some regions. For example, in June temperature was above normal in many parts of Europe, and in July rainfall was below normal over France. In most European countries July was the coolest month and August the wettest. In Russia, however, it was warmer than normal in all three months.

A persistent feature was a large area with pressure below normal, including most of western Europe and the eastern Atlantic Ocean. From May to June the monthly mean pressure fell by some 10–15 mb. in the region from Greenland to Scandinavia while it rose about 6 mb. in the Azores region. The resulting pressure gradient gave winds stronger than normal from the Atlantic across the British Isles, westerly in June and north-westerly in July. In August mean pressure was below normal over a very large area including the whole of Europe and most of the North Atlantic Ocean.

The data in "World weather records"[1] show that in 1882 there was a bad summer similar to that of 1954. The pressure anomaly charts for 1911–40 show no year in which the pressure changes from May to June were quite comparable with 1954 in magnitude and extent; the nearest approach was in 1927, when the summer was a poor one.

Dr. Pepper next referred to the weather of the summer in some other parts of the world. In west Africa temperature was some 2–4°F. below normal, and rainfall 50 per cent. above normal in many places, while the seasonal depression over north Africa was about 2 mb. deeper than normal. In south Africa the season, winter, was much wetter and cooler than normal and the mean pressure was also below normal. In the United States the summer was on the whole warmer and drier than normal. The Indian monsoon rainfall in June and July was generally heavier than normal and so was the rainfall in Japan and Malaya.

Some factors which possibly affect the pressure distribution in the North Atlantic have been discussed by C. E. P. Brooks[2]. One of these factors is the mean pressure gradient between Nova Scotia and Greenland; if this is greater than normal, as it was this summer, Brooks suggests that cold water is brought down into the North Atlantic in larger volume than usual, and in summer this tends to be associated with poor weather in western Europe. Another factor is the strength of the NE. and SE. trade winds over the Atlantic, the argument being that these winds affect the strength of the Gulf Stream; in particular, if some 15–21 months previously the trade winds were below normal, the flow of the Gulf Stream would be weakened, with a lowering of sea temperature in the North Atlantic.

Mr. A. Gilchrist, of the Forecasting Research Division, considered the summer from the large-scale synoptic aspect. His contribution was illustrated mainly

with 5-day mean 1000–500-mb. thickness charts for the northern hemisphere on which the mean depression tracks were also displayed. These showed that the synoptic situations in the Atlantic during the summer were predominantly of two types:—

(i) A ridge in the 1000–500-mb. thickness pattern over the Atlantic and a trough over or near the British Isles, with depressions approaching the British Isles from the north-west. This type was particularly persistent for a period near the end of June and the beginning of July.

(ii) A very large trough in the 1000–500-mb. thickness pattern over the Atlantic with Great Britain on its forward edge and with depressions approaching the British Isles from the south-west. This type occurred about the beginning of June but more especially at the end of July and during the first half of August when it was very persistent. It was responsible for the large rainfall totals recorded in southern England during August.

Mr. Gilchrist suggested that (ii) is a much more unusual summer type than (i).

The 5-day mean thickness anomalies for the hemisphere showed that a pattern with three major long waves was established before the beginning of July and persisted throughout July and much of August. The associated positive thickness anomalies were situated over northern Canada, north European Russia, and north-east Siberia. With this basic pattern established, the Atlantic synoptic situation might then be expected to be predominantly of type (i) or type (ii), in either case with an upper trough over much of the Atlantic and western Europe.

Mr. D. Dewar dealt with upper air climatology for the period under review. Upper air temperatures over Crawley and Lerwick during June, July and August for each of the years 1945–54 were shown plotted as departures from the average for this period, together with a seasonal diagram showing the cumulative departure from average of the three months. Over Lerwick tropospheric temperatures were not unusually low, and were, in fact, above average at 700 and 500 mb. in June. Over Crawley temperatures were below average especially in July, and the persistence of low mean temperatures throughout all three months made 1954 an outstanding year. The stratospheric temperature anomalies, shown by the 200-mb. diagrams, were generally the reverse of those in the troposphere. An examination of daily values of temperature at these two stations shows that the low mean temperature was due more to the persistence of temperature below average than to the occurrence of very low temperature. Temperatures below the minima for the period 1945–53 were recorded at Crawley on only two days, early in July, and at Lerwick not at all.

A study of percentage wind frequencies at 700 and 500 mb. for 1954 and 1948–53 shows that over Lerwick there was a large deficit of wind in the south-to-west quadrant and an excess of wind between NW. and SE. through NE., produced largely by the August distribution. Crawley data show that in June and August the 1954 distribution was not remarkably different from that for 1948–53, apart from an excess of NE. winds, but in July there was a striking preponderance of W.–NW. winds.

To study conditions over the northern hemisphere, isotherms and contours of isobaric heights for 700, 500, 300 and 200 mb. for the three summer months of

1954 were compared with the corresponding average charts for the period 1949–53. Long-period normal charts for these months are not yet available. The comparison showed that in June and August 1954 there were few outstanding departures from average; the most noticeable were the areas over northern Canada and to the north-east of Scandinavia with temperatures above average in the troposphere in August. An interesting feature of these two months was that though temperatures were below average over England and western Europe they showed little difference from average in the Iceland–Greenland region. July showed a number of striking divergencies from normal. The isotherms indicated a very marked warm area north-east of Scandinavia and a cold pool over the North Sea; over the Hudson Bay region and eastern Siberia temperatures were above average. The contours showed that a trough to the west of Greenland on the average charts had been displaced to a position where it extended south-eastwards from Iceland over the North Sea giving a flow of polar air over the British Isles. Contour heights were also below average over central U.S.S.R. and the west of the United States, and above average over eastern Siberia, the Hudson Bay region, and to the north-east of Scandinavia, giving a well marked wave-like pattern with three maxima and three minima as already noted by Mr. Gilchrist.

Mr. R. F. M. Hay referred to the temperature anomalies over the North Atlantic during the winter of 1953–54 and the spring of 1954, which he illustrated with diagrams. At the ocean weather stations in the western North Atlantic there were fairly large positive anomalies of air temperature from December to March or April. At station I (south of Iceland) there were negative anomalies from May to September, exceeding 2°F. in June and July. At station J (400 miles west of Ireland) negative anomalies persisted from February to September, although they were less pronounced than at station I. The sea-temperature anomalies were positive at stations I and J until June but became negative in July and thus tended to follow rather than precede the air-temperature anomalies. In the Denmark Strait and Davis Strait the air-temperature anomalies were mostly positive throughout the period.

These results are corroborated by seasonal air-temperature anomalies obtained from observations from "selected" ships, and related to the normals for the period used in preparing atlases in the Marine Branch (1887–99, 1921–38). For the winter of 1953–54 anomalies of air temperature were mostly positive, and of sea temperature markedly so, particularly to the west and south-west of the British Isles, even after allowing for a secular warming of 1°F. or more which has occurred over the north-east Atlantic during the past half century. In the spring of 1954 similar positive anomalies for air and sea temperatures still showed to the west of the British Isles and were most marked in the area of the Gulf Stream south of Nova Scotia and Newfoundland; but the central and northern North Atlantic anomalies were mostly negative. As very few ship observations become available in the Marine Branch within six months of the period to which they refer, it is not yet possible to provide comparable data for the summer of 1954; however the air-temperature anomalies for June in the eastern half of the North Atlantic showed even larger negative values than for the spring, suggesting a continuation of advection of air from the north-west. The observations which indicated positive anomalies just south of Newfoundland and large negative anomalies in the adjacent area to the east seemed doubtful at first, but confirmation of their accuracy is

found in the weekly ice charts issued by the United States Hydrographic Office, which show that at the end of May bergs had drifted as far south as latitude 40°N. in longitude 48°W. This position coincides with that of the negative sea-temperature anomalies, leaving little doubt that the survival of the bergs in a position so much further south than usual was due to their transport by a current colder than normal.

The distribution of air-temperature and sea-temperature anomalies over the northern North Atlantic at the beginning of the summer of 1954 was thus broadly in agreement with the anomalies which would be expected in association with the 1000–500-mb. thickness pattern, as described by Mr. Gilchrist. The air-temperature anomalies followed this pattern and sea-temperature anomalies conformed with a delay of a month or two. There was no suggestion that the sea-temperature pattern resulted to any marked extent from advection of cold or warm water apart from the behaviour of the Labrador current already described.

Mr. Hay later added that it is unlikely that the large number of bergs had any relation to the character of the summer of 1954 in the British Isles. Annual statistics show that in previous years there has been no relation evident between the number of icebergs off Newfoundland and the wetness or coolness of the summer in this country. This is hardly surprising since all the bergs in the Labrador current originated from glaciers in north-west Greenland and take some one to two years to reach the Newfoundland banks. The bergs in the east Greenland current do not enter the Labrador current at all as they melt in the Davis Strait. A more likely cause of the large number of icebergs off south-east Newfoundland in May and June lies in the positive air-temperature anomalies which were found in the Davis Strait in winter and spring. This would help to speed up the breaking of the coastal ice and release at an earlier date than usual bergs which had been frozen in among the coastal ice at the start of the previous winter.

General discussion.—*Mr. E. N. Laurence.*—The analysis of the recent British summer is not complete without considering conditions during the preceding winter and spring, including a survey of snow and soil moisture. The May 1954 chart shows a pressure anomaly of up to +8 mb. for the Greenland–Iceland–Scandinavia region, while in the south of Europe there is a small negative pressure anomaly, suggesting an abnormal easterly wind component across Europe during May. Easterly winds are associated with low humidity and abundant sunshine and assist in drying out the soil. Aided by the mild winter, and its deficit of snow, this drying out induced a soil-moisture deficit on the continental scale by the end of May. The effects on the characteristics of the soil such as its thermal capacity, conductivity and porosity, would lead to high surface temperatures and tend to produce a more intense or prolonged summer monsoon effect. The latter was reinforced by the accumulation of cold air to the north-west of Europe during May. This theory of a strong monsoon effect is supported by the anomalies of the following months. June showed a pressure anomaly of −3 mb. or more in high latitudes, a temperature anomaly of +2°F. in central Europe and −2°F. on the western seaboard. This situation persisted well into the summer. It would not be surprising if abnormally high pressure to the north-west of Europe were one of the prognostics of a bad summer in Great Britain, for this pressure anomaly probably reflects the intensity of the Eurasian monsoon. The normal change

in mean pressure between April and May[3] shows an isallobaric low of −5 mb. over China and a high of 3–5 mb. over west and north-west Europe and the North Atlantic. Thus the anomaly in the May 1954 pressure reinforces this normal behaviour. The symptoms of a strong monsoon effect may well exist simultaneously throughout the Eurasian land mass, and the European pressure anomaly for May is probably only one of several prognostic aids available from a study of the earlier Asiatic monsoon.

Mr. H. C. Shellard.—This summer might not have attracted quite so much attention if May and September 1954 had not also given us such poor weather. It is important not to treat the weather of the three summer months as an isolated event. The effect of the inclusion of May and September on a comparison of the 1954 summer with earlier summers should be considered. The main differences are that over England and Wales as a whole, in spite of a May which was wet and dull and a September which was wet and cool, 1954 came out comparatively warmer and drier than when the three monthly period was considered; that 1912, mainly because of its exceptionally cold September, was, over England and Wales as a whole, not only duller and wetter but also cooler than 1954; and that for Scotland the inclusion of May and September, both of which had been wetter this year than any of the months June–August, brought the 1954 summer up from sixteenth to sixth in order of wetness this century. For London similar comparisons can be taken back into the nineteenth century, and it is found that for June–August both 1879 and 1888 were wetter, cooler and duller then 1954, but for May–September 1879 only was worse than 1954 in all three elements. This century London has had no summers worse in all three elements than that of 1954, either on the three-monthly or the five-monthly basis, though several have been worse in two elements.

Mr. A. H. Gordon.—CLIMAT charts provide a valuable tool in any attempt to explain why the weather behaves in a particular way for a given month or season. The physical climatological process is going on all the time the world over. In some areas the process is speeded up—those are the areas with anomalies of like sign to the average climatological change in the mean values of chosen parameters from one month to the next; in other areas the process is slowed down. Such areas can be identified on CLIMAT charts. It is conceivable that an acceleration or retardation in the speed of the climatological process in one place may be related to similar phenomena elsewhere and consequently with subsequent anomalies in the actual mean values. For this reason it would be useful to construct in addition, monthly CLIMAT charts showing the anomaly in the speed of the process of annual change.

Mr. J. S. Sawyer.—It is interesting to note that the distribution of rainfall and temperature anomalies over North America was essentially the same in the three months June, July and August, whereas the surface-pressure-anomaly pattern was almost reversed between June and August. Probably the most persistent synoptic type during the summer and particularly in July was that in which a ridge of high pressure extended northward in the Atlantic from the Azores with a north-west flow over the British Isles. This type is common in summer, particularly in July, and 1954 is remarkable, not for its occurrence but for the lack of intermission with warmer and sunnier weather situations.

Cmdr C. E. N. Frankcom.—One of Mr. Hay's maps shows the position of icebergs near the Grand Banks unusually far south. I suggest that it is not the

presence of the bergs themselves or the effect of their melting which would cause any appreciable effect on the sea temperature. The significance of this position of the bergs does not mean that they are necessarily any bigger than normal, but that they have disintegrated more slowly, and that there is either an increase in strength of the Labrador current or a decrease in its temperature compared with normal years. It seems that this might have an eventual effect on the temperature of the Gulf Stream. It would perhaps be worth while examining the records of the United States Coast Guard whose vessels make routine oceanographical observations in the Labrador current to see if they provide any evidence to support this.

Mr. H. H. Lamb.—I agree with Mr. Sawyer that the circulation pattern represented by a great warm ridge over eastern North America and much of the Atlantic giving a north-westerly weather type over the British Isles is a common one in summer, but in 1954 it was uncommonly predominant or persistent. The other chief type occurring this summer was associated with a thrusting far south of the mean thermal gradient and depression tracks over the eastern North Atlantic, as mentioned by Mr. Gilchrist. Elsewhere in the hemisphere the many anticyclones (albeit with central pressures only 1010–1020 mb.) in western Siberia and the Urals region through the high summer period in 1954 seemed a remarkably unusual feature, perhaps related to the unusual shape of the polar-basin anticyclone with pronounced lobes towards the Urals. This in turn might be related to the calm weather of February 1954 in the Barents Sea, favouring the production of more sea ice than in most years, though data about the ice in this region are still lacking.

Dr. R. C. Sutcliffe.—The opening speakers have provided a very full and useful description of the actual happenings of last summer, but there remains the problem of relating the weather anomalies to physical causes and mechanisms. In this respect we have hardly reached the stage of knowing what problems to formulate, what questions to ask. The world charts of weather anomalies shown by Dr. Pepper are characterized by considerable small-scale patchiness, but underlying this there is some suggestion of a coherent large-scale pattern. The anomalies of British weather appear to be connected with processes on at least the hemispherical scale. The summer of 1954 was characterized in the upper air by a quasi-persistent three-ridge wave pattern of large amplitude, with the crests over America, European Russia and eastern Siberia. In the Atlantic–European sector, this pattern was associated with the mean belt of upper flow lying well to the southward and with negative temperature anomalies extending into quite low latitudes. There are grounds for hoping that studies of the large-scale circulation patterns will throw light on the underlying causes of seasonal anomalies of weather.

Prof. Gordon Manley.—Among comparable summers in the past I was rather surprised not to hear more of 1922 which was persistently cool, dull and breezy—in German parlance one of "vigorous European monsoon". To many southerners the noticeable feature of 1954 was the unusually cool breeziness, normally appropriate to our northern uplands. So far as my reduction of older records was valid I have taken out the rough data, which showed that 24 summers in the last 256 could be called consistently cool, the criterion being all three months 2°F. or more below overall average; that is about one in ten. 1954 ranked about fourteenth, and was thus not exceptionally unusual; what was unusual was the lapse of 32 years since the last cool summer.

Both 1922 and 1902 were cooler, but with regard to the majority of such cool summers if the overall mean is compared with the 30 "surrounding" years the deficit rarely exceeds that of 1954, namely 2·6°F. Only three significantly greater deficits occurred (1860, 1816 and 1725) of which the last two were associated with noteworthy ash eruptions. It would therefore appear that 1954 represents about as large a strain of the earth's circulation as we should fairly expect, in the absence of some additional factor such as violent eruptions.

Mr. R. G. Veryard.—I was interested to hear Prof. Manley refer to the possible association of climatic change with volcanic eruptions, as I have recently been studying the literature on the subject. The result has not been very enlightening. As is well known, Humphries[4] put forward the view that the net effect produced by volcanic dust in the upper atmosphere, as in the case of the explosions of Katmai, would be, if long continued, a lowering of the surface temperature by several degrees Centigrade. There certainly appears to be evidence that after volcanic eruptions there has been a reduction, at least in some areas, in the amount of direct solar radiation received at the earth's surface. On the other hand, Gentilli[5], after examining world temperatures subsequent to the eruptions of Krakatoa (1883), Katmai (1912) and in the south Andes (1921), concluded that there is no climatological evidence that volcanic eruptions may cause a general lowering of temperature in the year immediately following, even in regions very near to the erupting volcano. Although dust in the atmosphere may not be so important a factor in determining the magnitude and times of occurrence of meteorological changes of insolation intensity at the earth's surface, as suggested by Humphries, nevertheless it can hardly be disputed that variations in the turbidity of the atmosphere may well be responsible for minor climatic changes. Such variations cannot be due solely to volcanic dust. Apart from the dust which we put into the atmosphere ourselves, there is the fine meteoric dust brought in at high levels which seems to form a permanent, but variable, part of our atmosphere. Maybe the resulting variations in the overall energy budget are very small but is it not possible that the local effects, i.e. in regard to the intensity and distribution of heat sources and the consequent modifications of the circulation pattern, are out of proportion to the relative amounts of energy involved?

Mr. J. M. Craddock.—I would like to emphasize that the abnormal weather of the British Isles was not an isolated occurrence but was accompanied by abnormalities over a large part of the northern hemisphere, certainly extending from north-west Canada across the Atlantic and Europe to north-west Siberia. This fact points to a large-scale disturbance of the circulation rather than anything purely local. It is also evident that the position of the long waves in the upper air flow has an important, almost a controlling, influence on the weather in particular regions so that any method of long-range forecasting must predict the position of the nearest long waves if it is to have any chance of success. Mr. Hay's data suggest that abnormalities of sea-surface temperatures are the results rather than the causes of persistent abnormalities in the temperature of the air above.

REFERENCES

1. Washington D.C., Smithsonian Institution. World weather records. *Smithson. misc. Coll., Washington D.C.*, **79**, 1927, **90**, 1934 and **105**, 1947.
2. BROOKS, C. E. P.; The role of the oceans in the weather of western Europe. *Quart. J. R. met. Soc., London*, **56**, 1930, p. 131.

3. GORDON, A. H.; Seasonal changes in the mean pressure distribution over the world and some influences about the general circulation. *Bull. Amer. met. Soc., Lancaster Pa*, **34**, 1953, p. 362.
4. HUMPHRIES, W. J.; Physics of the air. New York and London, 1929.
5. GENTILLI, J.; Present-day volcanicity and climatic change. *Geol. Mag., London*, **85**, 1948, p. 172.

NIGHT COOLING CURVES FOR WAHN, GERMANY

By W. J. BRUCE

Parry[1] has produced a curve of the variation in time of the evening temperature discontinuity for Shawbury over the years 1949–53. A striking feature of this curve was the levelling out of the curve from mid March to the end of April. Similar curves have been prepared for Wahn for the years 1952 and 1953 as given in Fig. 1. Nights with average cloudiness of 2 oktas or less were used.

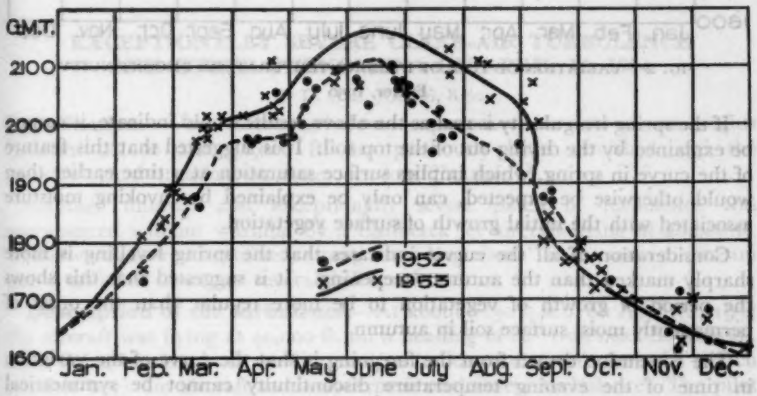

FIG. 1—VARIATION OF TIME OF EVENING TEMPERATURE DISCONTINUITY
Wahn, 1952 and 1953

The marked irregularity from mid March to the end of April agrees well with that found by Parry. A further irregularity is apparent in late summer where the curve shows a pronounced fall. A closer examination of Saunders's curve for Exeter[2] shows the possible existence of two similar irregularities. In view of the agreement between the Wahn and Shawbury curves a suggested redrawing of that for Exeter is given in Fig. 2.

Saunders[2] explains any irregularity in the curves as an effect of moisture in the top soil, and relates it to rainfall or the change from generally dry to permanently wet top soil.

Curves of this nature show the time throughout the year when the surface air reaches saturation and dew forms. The levelling out of the curve in spring time shows that saturation is reached earlier than would be expected on the basis of a steady increase in time. The fall of the curve in early autumn, which is well marked in Saunders's curve for Northolt[3], shows that similarly saturation has been reached earlier than would be expected on the basis of a steady decrease in time. This latter effect is attributed by Saunders to the seasonal transition to permanently wet top soil.

Cole Memorial Library

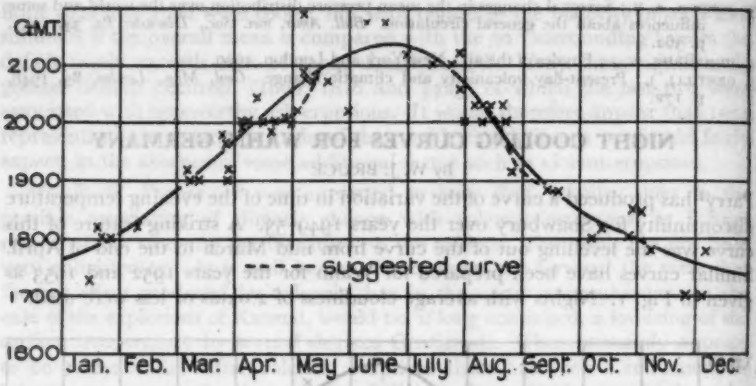

FIG. 2—VARIATION OF TIME OF EVENING TEMPERATURE DISCONTINUITY
Exeter, 1950

If the spring irregularity is real as the above results would indicate, it cannot be explained by the drying out of the top soil. It is suggested that this feature of the curve in spring, which implies surface saturation at a time earlier than would otherwise be expected, can only be explained by invoking moisture associated with the initial growth of surface vegetation.

Consideration of all the curves indicates that the spring levelling is more sharply marked than the autumn steepening. It is suggested that this shows the period of growth of vegetation to be more regular than the onset of permanently moist surface soil in autumn.

The conclusion drawn from the foregoing is that the curve of the variation in time of the evening temperature discontinuity cannot be symmetrical about the summer axis.

The site of the thermometer screen at Wahn is on a gently sloping heathland within 5 miles of the Rhine, and the soil is predominantly sandy apart from shallow clay layers. It would be interesting to make a comparison of the variation in time of the evening temperature discontinuity recorded by thermometer screens set in different exposures, one near a wooded area and the other as far away as possible from vegetation.

[The discontinuous change in spring has recently been independently confirmed in similar work in regard to St. Eval (see p. 76). In view of this, and the evidence from Wahn and Shawbury, it certainly seems a real feature. Mr. Bruce's redrawing of the Exeter curve is probably justified, though perhaps nothing more than a smooth curve could have been drawn into it without the later evidence. In any case it seems much more pronounced on the lighter soils (Shawbury, Wahn and St. Eval) than on the heavy clays (Northolt and Exeter).

It has been suggested in recent correspondence elsewhere[4] that release of water from vegetation in the evening may be a cause of, or at least contribute to, the evening temperature discontinuity. In that case we should probably seek the explanation of the spring discontinuity in the behaviour of the grass at the time of rapid growth, as Mr. Bruce suggests.

The difference between the mean curves of Mr. Bruce's Fig. 1 are of interest. In 1953 the spring discontinuity set in early. There is little difference in May and June and Mr. Bruce's 1953 curve might have been flattened over these months. In July and August there are quite striking differences, amounting to about an hour in the mean. Autumn appears to have set in very suddenly in September 1953, and thereafter the curves are similar.—W. E. SAUNDERS.]

REFERENCES

1. PARRY, T. H.; Night cooling under clear skies at Shawbury. *Met. Mag., London*, **82**, 1953, p. 368.
2. SAUNDERS, W. E.; Night cooling under clear skies, Exeter Airport. *Met. Mag., London*, **83**, 1954, p. 9.
3. SAUNDERS, W. E.; Some further aspects of night cooling under clear skies. *Quart. J. R. met. Soc., London*, **78**, 1952, p. 603.
4. SAUNDERS, W. E.; Night cooling under clear skies. *Quart. J. R. met. Soc., London*, **80**, 1954, p. 458.

EXCEPTIONALLY SEVERE CLEAR-AIR TURBULENCE AND OTHER PHENOMENA ON APRIL 14, 1954

By D. C. E. JONES, B.Sc.

Introduction.—Very severe turbulence experienced in clear air at heights between 28,000 and 41,000 ft. has previously been described and the meteorological situations on these occasions discussed[1,2].

Another unusual and exceptionally severe patch of turbulence was encountered without warning by a Canberra jet aircraft flying at 40,000 ft. There were also reports of very strong "standing waves" in the same air stream but at different times and several different locations.

Description of the turbulence.—At about 2130 G.M.T. on April 14, 1954 the aircraft was flying at 40,000 ft. on a heading of 84° true near Edinburgh. After flying in smooth air conditions at an indicated airspeed of 210 kt. (Mach number 0·7) the aircraft suddenly experienced severe turbulence. The pilot began to turn to the right to avoid the region of turbulence, but during the turn a severe gust lifted the port wing and rolled the aircraft on to its back. Full aileron control proved ineffective in preventing the roll, and while upside down the aircraft gained 500 ft. in altitude. Control was eventually regained and the aileron became effective again. The pilot then descended quickly and found that turbulence ceased below 38,000 ft. The aircraft returned to its base, landed safely, and no damage was found to have been suffered.

The only cloud in the vicinity of the incident was about 3 oktas of cumulus below 20,000 ft.

Meteorological situation.—Fig. 1 shows the surface chart for 0000 G.M.T. and Fig. 2 the 300-mb. chart for 0300 G.M.T. on April 15, 1954. The depression over southern Scandinavia was moving south-eastwards. An associated cold front was moving slowly southwards over northern England and was being followed by a secondary cold front which was over northern Scotland.

At high levels the whole of the British Isles and the North Sea were under the influence of a strong north-westerly air current. There are indications of a well marked jet stream with its axis extending from Iceland to the Shetlands to north-west Germany. Fig. 3 shows a cross-section from Valentia to Lerwick at 0300 G.M.T. April 15 which is the time nearest to that of the incident under discussion when temperature and wind soundings were made simultaneously.

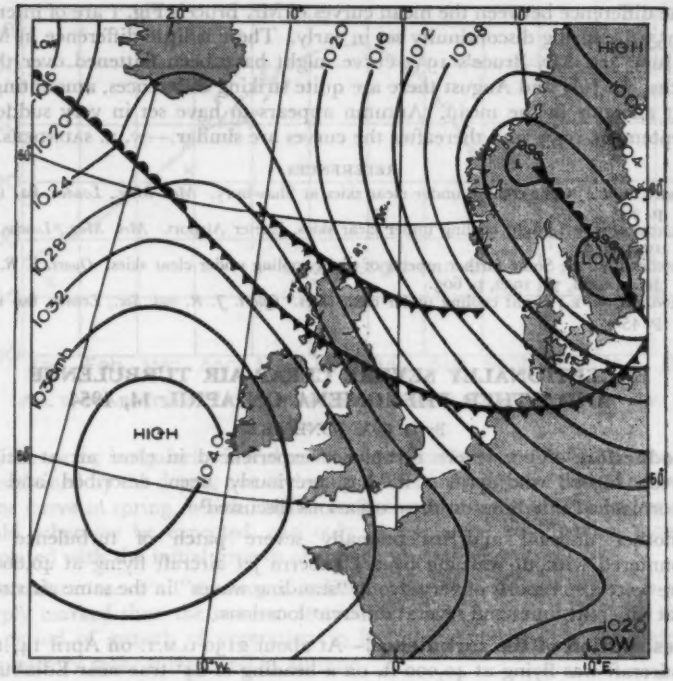

FIG. 1—SURFACE SYNOPTIC CHART, 0000 G.M.T., APRIL 15, 1954

Only upper winds were observed at 2000 on the 14th and those for stations in Scotland, Northern Ireland and northern England on the evening of the 14th are given in Table I.

TABLE I—WINDS AT 2000 G.M.T. APRIL 14, 1954

	Lerwick		Leuchars		Stornoway		Liverpool		Aldergrove	
ft.	°	kt.	°	kt.	°	kt.	°	kt.	°	kt.
45,000	318	125*	314	43	293	22	351	32	312	47
40,000	318	138	309	68	312	40	309	50	287	42
35,000	316	135	303	83	296	88	309	53	289	46
30,000	316	118	300	80	295	89	313	60	298	49
27,000	316	118	302	77	302	82	316	65	308	55
24,000	315	132	310	67	313	75	322	59	306	58

* This is the wind at 42,000 ft.; the wind at 45,000 ft., given in the *Daily Aerological Record* as 318° 144 kt., was computed from the last minute of the observation at the extreme range of the radar and is probably erroneous.

It will be seen that when the incident occurred the aircraft was flying in the upper troposphere, in a region of pronounced vertical and horizontal wind shear, on the warm side of the jet stream and above the level of the axis of the jet.

Standing waves.—After the flight the pilot stated that the only unusual feature he noticed before the onset of the very severe turbulence was found over the Midlands previously that evening. At a height of 40,000 ft. he noticed

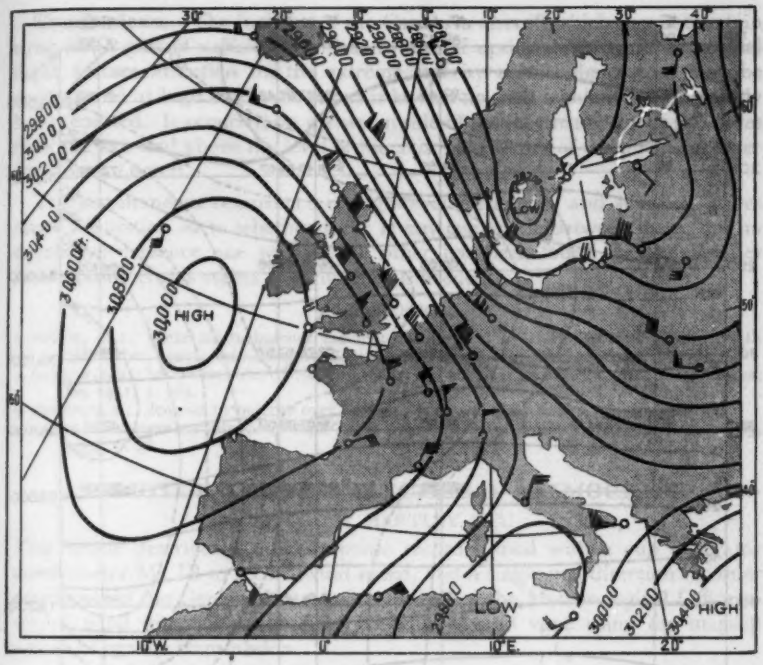

FIG. 2—300-MB. CONTOUR CHART, 0300 G.M.T., APRIL 15, 1954

up-currents and down-currents, and variations in the indicated airspeed which he thought were caused by standing waves.

Another interesting report showing the existence of strong vertical currents was received from the pilot of a jet fighter aircraft. While trying to fly straight and level at 35,000 ft. over Norwich at an indicated airspeed of 200 kt. at about 1100 the same day he noticed that the vertical-speed indicator and the altimeter were registering a rate of climb of 3,000 ft./min. He then tried to descend, and in his report states:—

I was now at 37,000 ft. I noticed that I was still in cirrus cloud. My rate of climb still showed 3,000 ft./min. and the altimeter reading rose quickly to just under 40,000 ft. I was still in cirrus cloud. I then opened the throttles and dived out to the south to carry out further R/T checks at lower altitudes.

My aircraft was heavily laden and should, once I had levelled off, have been unable to climb at anything more than 1,000 ft./min. at the beginning, and when the nose was down should have lost height at least at 2,000 ft./min., probably more.

There was no vestige of turbulence during the climbing incident which took place 10 miles south of Norwich.

The existence of standing waves in the air stream at lower levels has subsequently been confirmed by the large number of reports received from other aircraft, the heights at which they were reported varying from 4,500 ft. to 18,000 ft. and the rates of lift and sink ranging up to 2,000 ft./min.

Discussion.—There were other reports of high-level turbulence over the British Isles on April 14. The existence also of standing waves at various levels

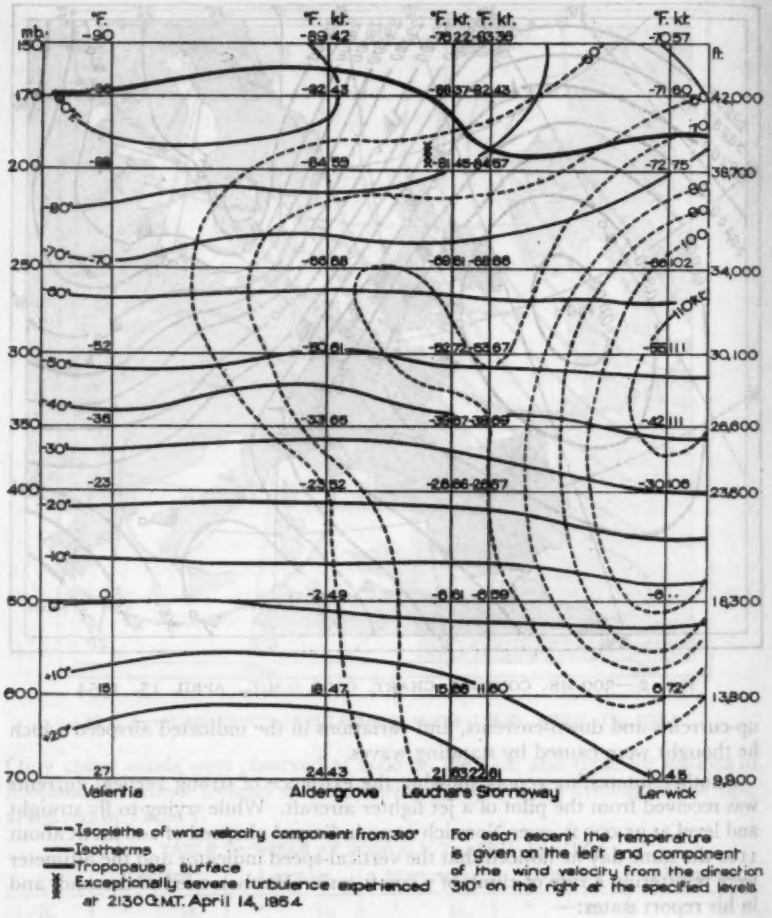

FIG. 3—CROSS-SECTION, VALENTIA–LERWICK, 0300 G.M.T., APRIL 15, 1954

at more or less the same time poses a problem as to whether the turbulence is in some way associated with standing waves which are generated when wind blows over a mountain range. Hislop tentatively suggested in his report on the British European Airways special investigational flights[3] that under certain conditions the waves might break—like the waves of the sea—and thus degenerate into turbulent motion. He quotes an occasion when a British European Airways Mosquito experienced smooth lift of about 1,500–2,000 ft./min. between 35,000 and 37,000 ft., which finally petered out into rather sluggish turbulence. It has also been suggested by Radok[4] that topography can be responsible at times for localizing and rendering turbulence severe within a favourable jet-stream region.

Conclusions.—The incident of the Canberra aircraft which encountered, in clear air, a gust of sufficient violence to turn it upside down while in normal flight focuses attention on the extreme severity of turbulence that may be encountered at high levels. So far as is known no such incident has previously been reported. It occurred on the warm side of the jet stream, about 250 miles from the axis and above the level of the axis. The depth of the turbulent layer was about 2,000 ft.

The simultaneous occurrence of high-level turbulence and standing waves raises a question as to whether there is any connexion between them, but no conclusive evidence one way or the other has been found so far. Further investigation of this aspect of turbulence is needed.

REFERENCES

1. HISLOP, G. S.; Clear air turbulence incident encountered by D-H "Comet" aircraft, 14th November, 1949. *Brit. Europ. Airways R.S.D. Notes, London*, No. 41, 1949.
2. BANNON, J. K.; Severe turbulence encountered by aircraft near jet streams. *Met. Mag., London*, **80**, 1951, p. 262.
3. HISLOP, G. S.; Clear air turbulence over Europe. *J. R. aero. Soc., London*, **55**, 1951, p. 199.
4. RADOK, U.; Severe turbulence at high levels over New South Wales. *Met. Mag., London*, **83**, 1954, p. 48.

REMOTE-RECORDING ELECTRICAL ANEMOGRAPH

By G. E. W. HARTLEY, M.A.

This article describes a quick-response recorder used with a cup generator anemometer Mk IB to record wind speed, and a single-pen direction recorder developed in the General Instruments Branch of the Meteorological Office to record wind direction in conjunction with a wind vane using the magslip system of remote transmission.

Wind speed.—A recorder to work with the standard Meteorological Office cup generator anemometer Mk IB has been described in the *Proceedings of the Institution of Electrical Engineers*[1]. It was subsequently found that if the speed scale on the chart was that derived from wind-tunnel tests, isolated gusts were recorded as much as 15 per cent. low, because the response of the recorder was not quick enough to enable it to follow the generator, although steady flow was correctly recorded.

The recorder was therefore modified by changes in the transformer and rectifier, which necessitated their being housed in a separate case instead of inside the recorder, and by altering the coil winding of the recorder so that it took a considerably larger current from the generator, the extra power so obtained enabling stronger hair springs to be used in the recorder. With these modifications the recorder will now follow the generator, and gusts are correctly recorded, as well as steady speeds.

Comparisons between this recorder and a remote-recording pressure-tube anemograph were made at South Farnborough for some months, the generator anemometer being supported on a side bracket from the top of the tower on which the pressure-tube anemograph head is mounted. Charts from both were tabulated in the General Instruments Branch and the tabulations showed close agreement in both mean and maximum values.

Two more recorders of the same type were obtained; wind-tunnel tests showed that their scale values were in close agreement with those of the original recorder so that the same charts could be used for all three with confidence.

These two recorders have been connected to two generator anemometers mounted on the 40-ft. tower on the roof of the meteorological office at Harrow and have been in operation for some months; their charts show close agreement, though there are sometimes differences due to interference between the two anemometers and other instruments on the tower. The recorder is shown in Fig. 1 (facing) and its dimensions in Fig. 2.

Accuracy and consistency of performance are rather difficult to assess; but the original recorder was calibrated in the wind tunnel before and after the South Farnborough tests, and no change of calibration occurred; and during the wind-tunnel tests, the "wind" speed was brought to a given speed from several other speeds both higher and lower and the speed was correctly recorded with an error not exceeding $\pm \frac{1}{2}$ kt.

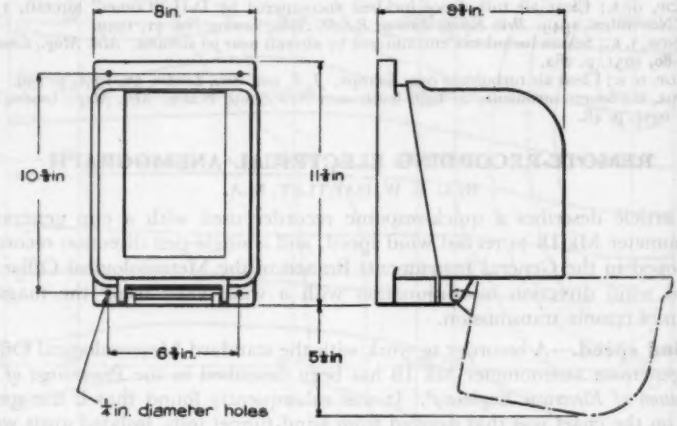

FIG. 2—DIMENSIONS OF THE QUICK-RESPONSE RECORDER

The inking system supplied by the makers of the recorder has proved very satisfactory; it consists of a fine tube, suitably shaped, one end of which dips in an ink-well situated at the axis of the pen movement, the other end carrying the writing nozzle and resting lightly on the chart. The spindle of the electrical movement carries a stirrup with V slots; the inking tube is pivoted on knife-edge supports which rest in these slots. The ink-well end of the tube moves only in the ink, not through it; the hole in the top of the ink-well through which the tube enters is only just larger than the tube so that very little dust can get in, and clogging of the tube does not occur. The weight of ink in the tube is constant, and the whole pen is balanced so that it will write with very little friction. Ink feed is by capillary, not siphon, action.

The chart is of 4 in. writing width, and has a speed of 1 in./hr. which can be altered to 3, 6 or 12 in./hr. by changing the driving gears. It is 65 ft. long, which gives a run of about 30 days using the 1 in./hr. time scale. A range of 0–90 kt. has been used, but it would be possible to provide a smaller range and larger scale for normal use, with an extra series resistance which can be switched in to increase the range and reduce the scale.

[*To face p. 112*

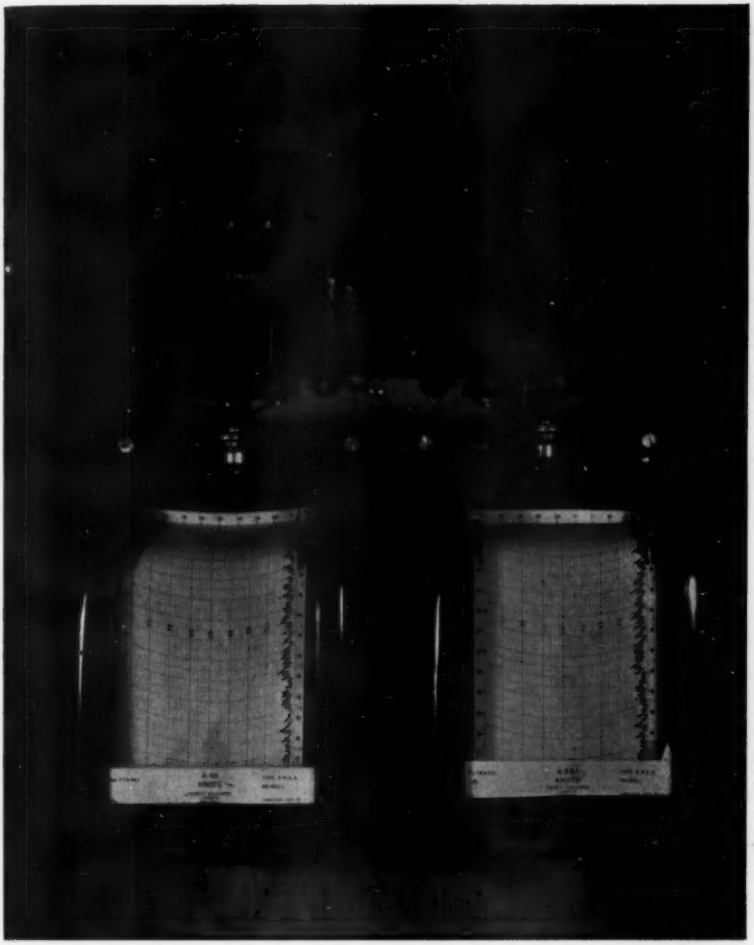

FIG. 1—QUICK-RESPONSE RECORDERS USED WITH CUP GENERATOR ANEMOMETERS MK 1B

FIG. 5—WIND-DIRECTION REMOTE RECORDER

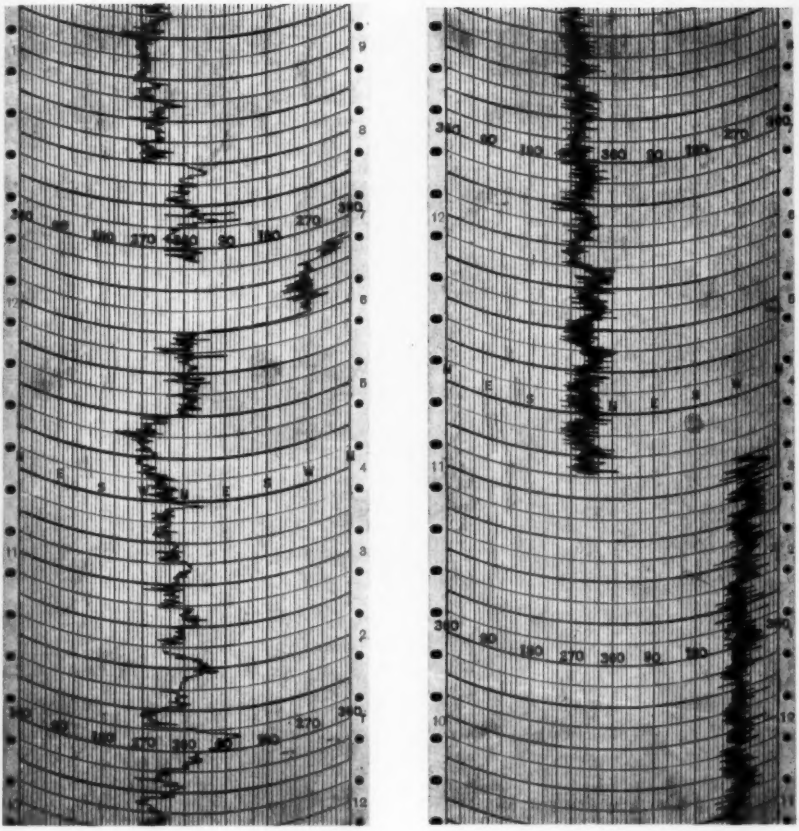

FIG. 6—SPECIMEN CHARTS FROM THE WIND-DIRECTION RECORDER

The speed of the charts was 3 in./hr. (left-hand scales); the left-hand chart was recorded with a wind speed of 2–6 kt., the right-hand chart with a wind speed of 8–20 kt. Re-centring took place at about 1217 on the left-hand chart and 1106 on the right-hand chart.

To face p. 113]

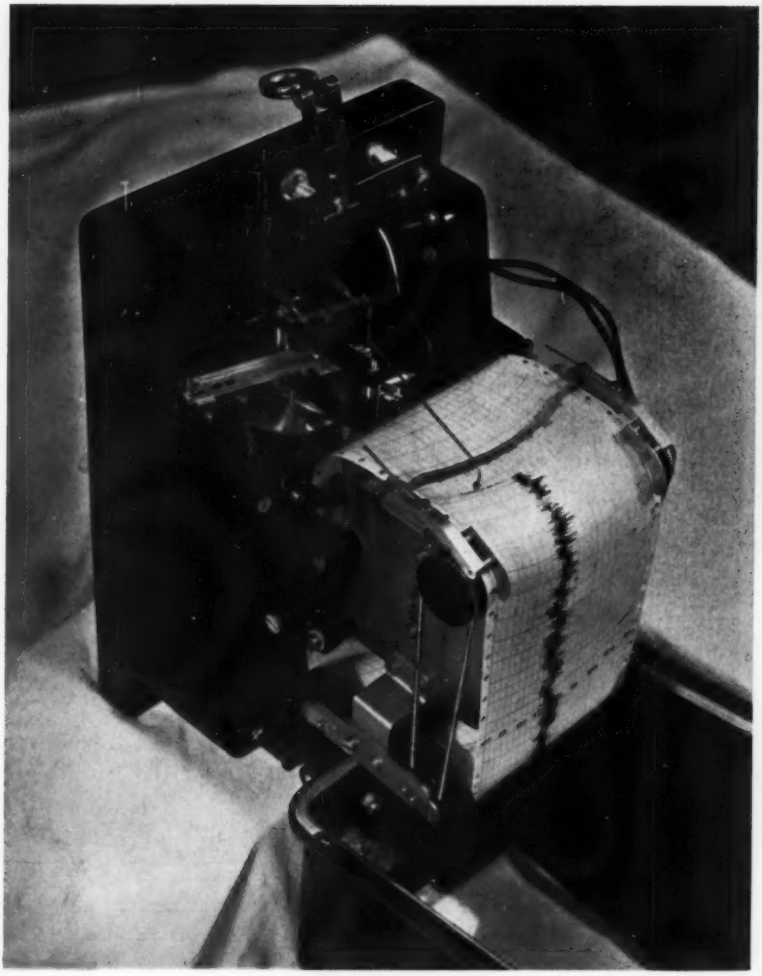

FIG. 7—SMALLER-SIZE WIND-DIRECTION RECORDER

As will be seen from the specimen chart (Fig. 3) the graduations are nearly linear above 10 kt. The anemometer cups start to revolve at 3·5 kt. and the record is of no value below 5 kt.

No trouble has been experienced with these recorders during trials; the only attention given is to top up the ink-well once a week and fit new charts when needed. The chart mechanisms used are synchronous motor driven but the makers can supply spring-driven mechanisms at a slightly higher cost.

The six recorders used for the Severn Bridge wind measurements over several years suffered only three occasions of chart motor failure, and two of change of calibration of the recorder; this was found to be due to faulty rectifiers, and when these were changed to another type as now used no further trouble occurred.

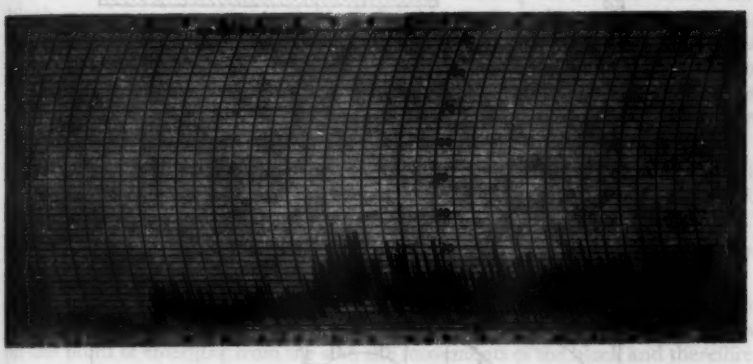

FIG. 3—SPECIMEN ANEMOGRAM FROM THE QUICK-RESPONSE RECORDER
Chart speed 1 in./hr. (bottom scale)

Wind direction.—For remote transmission of wind direction from the vane to the recorder, 2 in. magslip motors, type E2, are used. These operate from 50V. a.c. obtained from mains by a transformer, and form a synchronous link.

At present there is no standard Meteorological Office wind vane embodying 2 in. magslips, but they are commercially obtainable incorporating a mounting for the generator anemometer above the wind vane and magslip, so that only one support is needed for both instruments.

The wind-direction recorder is of the single-pen type developed in the Meteorological Office. In its original form it was shown at the Physical Society's Exhibition in April 1951 and was briefly described[2] in the *Meteorological Magazine*, July 1951.

In its present form it is shown diagrammatically in Fig. 4. The receiving magslip (1) is geared down 1 : 8 to a gear wheel (2) which carries eight evenly spaced pins (3). One of these pins engages with a slot in a specially shaped block (4) pivoted to a moving arm (5) which also carries the recording pen (6) by means of the stirrup (9). The axes of the gear wheel and moving arm are not coincident, and are so placed that when the gear wheel moves 45° from a central position, the slotted block disengages from the pin and is returned by a centring device (7) to the adjacent pin near to the central position. In the

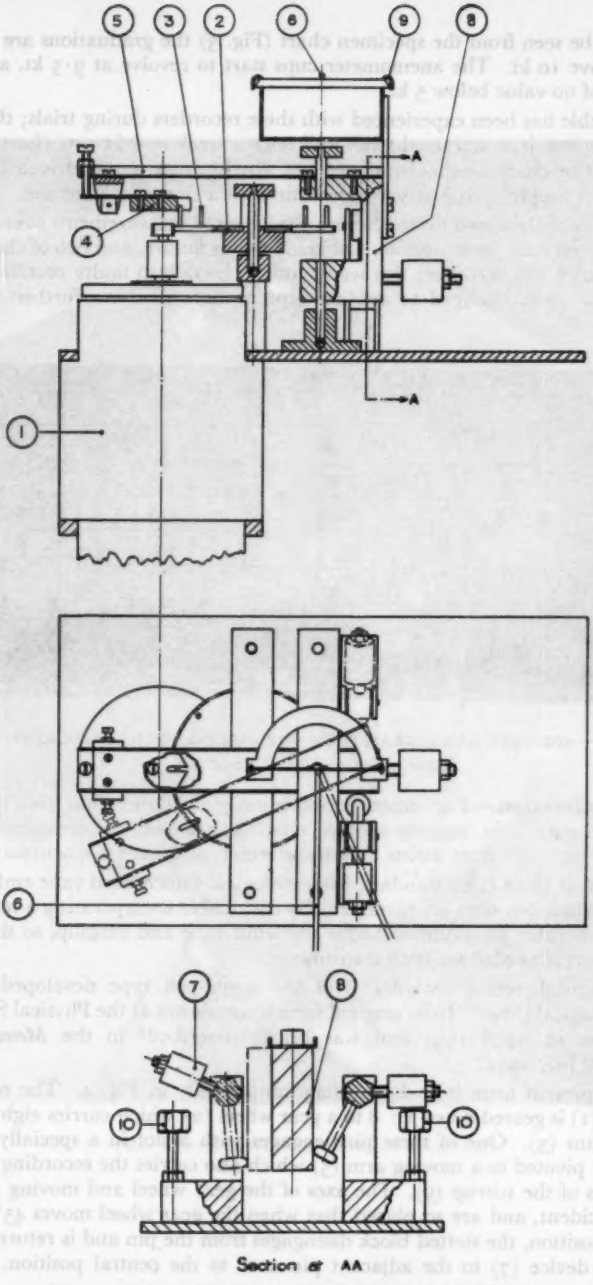

FIG. 4—LAY-OUT OF THE WIND-DIRECTION RECORDER

original design, the centring device was a torsion spring; this proved inconsistent in its performance, and was replaced by two pivoted and weighted levers (7) which are set so as to bring the part of the pen arm (8) on which they press to a central position by means of the adjusting screws (10). This system has proved very reliable. The movement of the arm from the central to the disengaged position corresponds to 360° of vane movement, and also to the movement of the pen from the centre of the chart to one or other edge.

The chart is marked with a range of 720° in direction; when the pen gets to either edge of the chart, the pin disengages from the slot, the centring device returns the pen through 360° (chart marking) to near the centre of the chart, and the slotted block engages with the pin nearest to the central position. The recorder is shown in Fig. 5.

There is a slight risk that when the arm is moving back to the centre the block may jump over, or stop short of, the central pin without engaging with it, thereby giving an incorrect record. In practice over several months trial re-centring has taken place many times and the block has only twice failed to engage. Specimen charts showing the appearance of the trace when re-centring occurs are shown in Fig. 6. In these charts the time scale is 3 in./hr. The centring device is adjustable but once set requires no further adjustment.

To reduce further the risk of wrong recording, users may be told that if at any time they see the pen near the edge of the chart they should move the block by hand to the central pin.

The chart mechanism and inking system are the same as those used in the wind-speed recorder.

There is a theoretical objection to the geometry of the system: as the pins on the gear wheel have a finite thickness, if recording takes place when the pin is on the point of emerging from the slot, the movements of the block and therefore of the pen do not exactly agree with those of the pin. In practice if this occurs, the block is always either released, or goes back fully on to the pin, and no wrong readings persist.

A later modification has been to reduce the size of the mechanism to allow it to go inside the same kind of case as the wind-speed recorder. This recorder, shown in Fig. 7, works perfectly satisfactorily.

Wind-speed recorders of the type described have been used for some years in the Falkland Islands and at Cardington and have given satisfactory service. The latest design has been undergoing trials at Harrow and has given no trouble.

Twelve complete instruments are now on order for operational trials; in these, the speed and direction recorders are to be combined in one case, with the speed and direction pens recording on the same (double-width) chart.

REFERENCES

1. HARTLEY, G. E. W.; The development of electrical anemometers. *Proc. Instn elect. Engrs, London*, **98**, Part II, 1951, p. 430.
2. London, Meteorological Office. 35th Physical Society Exhibition. *Met. Mag., London*, **80**, 1951, p. 202.

METEOROLOGICAL OFFICE DISCUSSION

Electronics applied to meteorological instrumentation

The discussion on Monday, January 17, 1955 held at the Royal Society of Arts, was opened by Mr. R. Almond of the Instruments Division of the Meteorological Office.

He stated that the greatest contribution of electronics to meteorological instrumentation had been in the investigation of the upper atmosphere, and that this field of work would be the only one considered. The main emphasis would be placed on the various electronic methods of measuring upper air temperature, pressure and humidity, upper winds and cloud height. Application of electronics to these and other meteorological instrument problems was increasing steadily, and as new techniques became established by research and the application of new materials, more and more of these problems would be solved.

Omitting the work on sferics, the free balloon meteorograph was the first upper air instrument to become electronic, taking the now familiar name radio-sonde. This introduced a new era for the forecaster in which upper air information became available on an all-weather basis with reception-time delay comparable with surface observations. From the first radio-sonde of Idrac and Bureau in 1927 have sprung the many systems now in use. In general the electronic requirements of the average radio-sonde have remained fairly simple, but improvements in electro-mechanical techniques, meteorological measuring elements, general components, and battery power supplies, have produced much more stable and sensitive instruments. Miniturization of components and reduction of power consumption of the newer valves have reduced size and weight considerably. As higher working frequencies enabled directional aerial systems to be employed in ground reception equipment, wind measurement from a single station became possible.

Very accurate radio and radar theodolite systems, combined with normal pressure, temperature and humidity sounding, are the latest development. These are made possible by the application of microwave techniques. Servo-mechanism development has made the following of airborne transmitters and passive microwave targets automatic, and also added this feature to the recording of information at the ground station.

The radar technique enables the transmission of megawatts of peak pulse power in pulses with as small a duration as $\frac{1}{2}$ μsec. and receivers can detect micromicrowatts of back-scattered power. This has led to the very important application of radar to the detection of storm and general precipitation areas, and the measurement of vertical cloud structure.

Airborne units are subjected to wide variations of temperature, pressure and humidity, and special care is necessary to eliminate unwanted circuit responses to those changes, which must only be measured by the appropriate meteorological units. New low-density foamed plastic materials forming heat insulating containers will greatly reduce this problem.

Consideration of various types of upper air instrument systems will illustrate the practical application of electronics in this field. Commencing with radio-sonde systems, four basic types are in use: (*a*) variable audio frequency, (*b*) variable radio frequency, (*c*) chronometric, (*d*) code.

Type (*a*) *Variable audio frequency.*—This has been adopted by the United Kingdom, America and Holland. The present British routine instrument is the Meteorological Office Mk IIB radio-sonde. The audio-frequency range is from 700–1,000 c./sec., and this variation is produced in a Hartley-type oscillator by varying the air gap of its mumetal-cored inductor. Three such inductors controlled by meteorological elements are connected in turn into the oscillator circuit by means of a windmill-operated switch. These elements are bimetal, aneroid capsule, and goldbeater's skin, and provide the necessary inductor air-gap variation for temperature, pressure and humidity respectively. The audio oscillator is compensated for both temperature and

voltage changes, and its output is fed through a buffer stage to amplitude modulate the transmitter carrier. The radio frequency is set within the range 27·5–28·0 Mc./sec. and the transmitter output is about 30 mW. Ground equipment consists of a communication receiver, an oscilloscope, a precision variable-audio-frequency oscillator, and a 1,000 c./sec. frequency standard. Transmitted modulation frequencies are measured by the Lissajou-figure technique and can be converted into the appropriate meteorological data.

The two main American radio-sondes in use at the present time operate on carrier frequencies of 400 and 1,685 Mc./sec. Audio-frequency modulation is controlled by varying the grid resistor of a blocking oscillator and lies within the range 3–200 c./sec. A thermistor and hygroscopic film give the required resistance variation for temperature and humidity measurement. Pressure is signalled at fixed audio-frequency high and low reference levels, and the pressure aneroid capsule operates a light contact selector switch which controls the signalling sequence.

The new Dutch radio-sonde uses three audio-frequency oscillators, whose outputs are mixed in a reactance tube which frequency modulates a carrier in the 27·5–28·0 Mc./sec. radio-sonde band. At the ground station a frequency-modulation receiver delivers the complex output signal to three band pass filters which separate the audio-frequency components. The three simultaneously available signals can be read off directly on frequency meters, and are automatically registered with time separation by a rapid response recorder. Thermistors are used for pressure and temperature measurement and goldbeater's skin for humidity. Pressure is measured hypsometrically, the thermistor giving the boiling point of the working liquid which is a Freon.

The British lightweight radio-sonde, for temperature measurement only, employs a fixed inductor in the audio-frequency oscillator in conjunction with a variable capacitor. The inductor employs a pot-type core of a new ferrite composition, whilst the capacitor is a silvered thin-walled cylindrical type, whose ceramic dielectric is barium strontium titanate. The capacity varies by a factor of four over the working temperature range, giving an audio-frequency variation from 3,000 to 7,000 c./sec. Ground equipment is similar to that used for the British Mk IIB sonde, and the instrument can be carried by a 100-gm. balloon.

Type (*b*) *Variable-radio frequency.*—This has been adopted by Finland, Japan, and in the past by Germany.

The Finnish radio-sonde designed by Vaisälä, varies capacity mechanically by means of bimetal, aneroid and hair for temperature, pressure and humidity measurement. The three elements are connected separately into the radio-frequency circuit along with two fixed reference capacitors by a five-way windmill-driven switch. By referring the three meteorological variables to the reference signals, errors due to permanent frequency drifts in the main circuit are eliminated. At the ground station the receiver tuning condenser is mechanically coupled to a recorder.

Type (*c*) *Chronometric.*—This has been adopted by Canada, Switzerland, France, Germany, India, and was at one stage used during development work on a British radio-sonde theodolite system.

For all these sondes the transmitter carrier is interrupted or shifted by reference and meteorological signals. The time intervals between such discontinuities are proportional to the meteorological variables, and are either measured in terms of the actual spacing between recorded reference and meteorological signals, or in terms of the number of pulses of a fixed frequency which occur between signals. The scanning element can be in the form of a rotating single-turn helix (German, Indian), flat spiral (Canadian), or radius arm (French and Swiss). The scanner drive is provided by electric motor for the Canadian and French instruments, and clockwork motor for the Swiss, Indian and German instruments.

Type (*d*) *Code.*—This system is used in the Russian Moltchanoff sonde, in several past and the latest German radio-sonde, and in the American drop-sonde used by weather reconnaissance aircraft. Electronically these sondes only involve the suppression or shifting of a radio-frequency carrier by standard morse or other code modulation. The latest German instrument uses a number code 00–99, and this can be repeated approximately five times to give a sub-division of 500 parts over the working range of measurement. The code symbols are printed by an anodic process on a grooved partial aluminium cylinder. Ground equipment for coded radio-sondes is simply a communication receiver.

The importance of upper wind data has led to the development of radio-sonde and radar-sonde theodolite systems. The important factor here is a high carrier frequency which enables the production of an aerial system with a very narrow beam width.

The American 400 Mc./sec. wind-measuring equipment depends on the electronic switching of sections of a stacked dipole aerial array. Manual aerial control enables matching of elevation and azimuth signals on a cathode-ray tube, the appropriate angles being read directly at one-minute intervals. The signals are provided by the 400 Mc./sec. radio-sonde from which height information is obtained to complete wind-computation data.

The latest American 1,685 Mc./sec. wind-measuring equipment is fully automatic as regards target following, and the printing of azimuth and elevation angles. A paraboloidal aerial is used and conical beam scanning gives the necessary target-position information to the auto-follow circuits which keep the aerial aligned on the target, this being a 1,685 Mc./sec. radio-sonde. Again height information from the radio-sonde completes the wind-data requirement.

The new British radar-sonde theodolite system carries automatism a step further by measuring target range and also computing height, wind speed and direction as well as recording temperature, pressure and humidity in a form easily convertible to meteorological values. A transponder system is employed in which the radar-sonde receives 2 μsec. pulses on 152·5 Mc./sec., and re-transmits them on 2,850 Mc./sec. The meteorological units initiate the triggering of a second pulse from the airborne transmitter with a time delay dependent on the meteorological quantity being measured. This delay is measured in pulses by the ground equipment.

Standard gun-laying radar equipments are used in conjunction with passive targets attached to balloon trains, with or without radio-sondes, for upper wind determination. These equipments provide manually or automatically all the wind-measuring data required.

Radar equipment with an 8-mm. operating wave-length has been shown capable of detecting cloud bases and tops, but is unsatisfactory for the measurement of bases below 1,000 ft.

Optical radar is the basis of an experimental pulsed-light cloud-base meter capable of base measurement day or night over an average range 0–12,000 ft. Paraboloidal mirrors of 20 in. diameter, 25 ft. apart, and aligned with optical axes in the vertical, are used for beaming the transmitted $\frac{1}{2}$ μsec. light pulse and collecting its back-scattered component. The amplified received pulse is displayed on a calibrated time base and its commencement position gives the height of the cloud base.

In conclusion we can consider possible future developments. A standard radio-sonde against which all others could be compared is very desirable, and if the sonic sonde were perfected, it would at least settle radio-sonde temperature-measuring accuracy. Balloon performance should be improved to enable the attainment of 100,000 ft. regularly, and 150,000 ft. on special occasions. A simple humidity element with response time and accuracy unaffected by ambient temperature is a pressing requirement, whilst a multi-purpose ground radar set would make the application of this important new technique a more economic proposition. In general, electronics will be called upon more and more to measure, transmit, present and compute meteorological data.

Mr. Clark in opening the general discussion considered the new problems arising out of the increased speed of modern aircraft. In these conditions it is necessary to make meteorological measurements automatically. The two main problems are automatic following and accurate measurement of an electrical quantity. An example is the frost-point temperature determination. An automatic instrument has been developed for this type of measurement in which a thin platinum film is maintained at the frost-point temperature by opposed heating and cooling. This is achieved by a photo-electric-cell signal, dependent on the degree of frost deposit controlling the output of an amplifier which supplies heating power to the metal film. Continuously opposed to this heating

is the cooling of a copper rod, electrically but not heat insulated from the metal film, the main body of the rod standing in liquid nitrogen in a Dewar vessel. Two voltages proportional to the voltage and current across the film, are divided to give its resistance. As this resistance is dependent on temperature, a calibration for film temperature is possible. Another example is the electrical-resistance thermometer for which a self-balancing bridge based on the Callendar and Griffiths type has been developed. This follows the resistance changes by means of a binary scale relay-counting mechanism operated by the bridge out-of-balance current. The binary number at balance represents the required thermometer resistance. Changes of temperature over a range of 100°C. can be measured to 0·1°C. at a following speed of 1°C./sec. Space required for the present model is only 0·5 ft.[3]

Dr. Dell mentioned the enormously enhanced accuracy of the new radar theodolite installed at Crawley. Measurements of very fine wind structure were now possible, the equipment even detecting the swinging of a wind-measuring transponder rig about a fixed apex. In considering cloud-height meters, certain new phosphors show promise of application for modulated light sources at frequencies of about 10 Mc./sec.

Mr. Bibby described a daylight cloud searchlight being developed in the Instruments Division. Its beam is modulated at 340 c./sec. by a rotating shutter, and continuously sweeps between the horizontal and vertical. Some hundreds of feet away is a photo-electric detecting unit, pointing vertically. When the modulated searchlight beam illuminates the cloud base within the receiver beam, an audible signal is produced, and the searchlight elevation angle transmitted to the receiver point by a servo system can be noted at this instant. By triangulation the cloud height is determined. Though in its present form it will only detect cloud up to 2,000–3,000 ft. its chief advantage seems to lie in its adaptability to continuous autographic recording at a distant observing office.

Mr. Needham referred to the field trials of the pulsed-light meter at Northolt, giving the effective instrument range as 0–9,000 ft., though cloud echoes had been obtained several times from higher levels up to 15,000 ft. Improvements were suggested to ensure greater efficiency and convenience of operation. This method of cloud-height determination has distinct advantages over methods in current use despite certain limitations. No difficulties are experienced in receiving good returns from cloud in moderate precipitation, including snow. Further development will make the instrument a valuable day and night observing aid; forecasters and those connected with the operation of aircraft stand to benefit from the enhanced observing accuracy. The full usefulness of the instrument will not be known until the present research work is completed.

Dr. Scrase inquired if a radio-linked anemometer and wind-recorder system would in the long run be cheaper than a ground cabled system.

Cmdr Frankcom suggested that the pulsed-light system might be a useful addition to a weather ship's instruments, but thought better wind-measuring equipment was a more pressing requirement.

Mr. Durward mentioned the need for a remote cloud-height indicating apparatus; Mr. Almond, in reply, suggested that an automatic strobing technique applied to the pulsed-light meter would make remote recording a possibility. At this point Mr. Almond showed a series of slides depicting cloud-echo

photographs from a wide range of cloud types obtained with the pulsed-light meter.

Mr. Parry wondered if the cloud top could be measured with the pulsed-light meter; Mr. Almond suggested that there were certain cloud types which might yield both base and top information.

Mr. Harley suggested the difficulty of giving a true definition of cloud base. He welcomed the news of the American cloud-base and top meter, but had previously heard its value was somewhat limited.

Mr. Harper stated that the cloud-base and top meter only yielded satisfactory results with large-droplet clouds.

Mr. Murgatroyd, referring to Mr. Clark's statement, suggested that instrumentation was becoming too complex and accuracy of reading too great. This applied to the radar-sonde theodolite system which was the only one requiring ground and airborne transmitters. Mr. Clark regretted the complexity but claimed that it was unavoidable, whilst Mr. Almond stated that two transmitters were necessary for range determination with any transponder system, and that this determination would lead to more accurate wind data at all ranges and heights than obtainable with systems using radio-sonde heights in wind computations.

Mr. Sawyer saw no foreseeable use in the near future for a fully automatic computation system in actual weather forecasting. Only simplified atmospheric models could be adapted to this technique, and these only employed a very small quantity of the available upper air information.

The Director, in closing, remarked that the discussion had dealt mainly with the secondary communication techniques, and not with the primary measuring elements for pressure, temperature, etc. There was a need to look carefully into the accuracy of the available elements and to investigate all possible new alternatives.

ROYAL METEOROLOGICAL SOCIETY

Before the meeting began on January 19, Sir Charles Normand, on behalf of the Society, congratulated the President, Dr. O. G. Sutton, on the award to him of a knighthood, announced in the New Year's Honours List. The Society then proceeded to a discussion on air flow over mountains, which was opened by a summary of the following paper:—

*Corby, G. A.—The air flow over mountains**

Mr. Corby began by outlining the observational evidence of wind flow in the neighbourhood of mountains, particularly that of stationary lee waves. Evidence came mainly from the study of orographic clouds and from the reports of pilots, particularly glider pilots; and it seemed clear that stationary lee waves were more pronounced in stable conditions—in unstable air the flow was disorganized and turbulent—with wave-lengths of the order of a few miles. The amplitude of the waves increased upwards and then decreased at higher levels, and the air flow was rather smooth; vertical components as large as 2,500 ft./min. had been observed.

Mr. Corby then discussed briefly the theoretical work of P. Queney and R. S. Scorer who attempted to find mathematical expressions for wave motion over hill ridges. Queney's solution only gave a train of waves for hill widths of the order of 100 Km.—whereas Scorer's, being confined to smaller-scale phenomena in which it was possible to ignore the Coriolis factor, did give a train of waves under certain conditions of wind profile and stability. Scorer's simplified equation is

$$\frac{\partial^2 \psi}{\partial z^2} + \left(\frac{g\beta}{U^2} - \frac{1}{U} \frac{\partial^2 U}{\partial z^2} - k^2 \right) \psi = 0,$$

where β is the coefficient of stability depending on potential temperature and its gradient with height, U is the horizontal wind velocity and k is the wave number; and Scorer showed that wave trains were possible in the lee of a ridge if the parameter

Quart. J. R. met. Soc., London, **80**, 1954, p. 491.

$$l^2 = \frac{g\beta}{U^2} - \frac{1}{U}\frac{\partial^2 U}{\partial z^2}$$

increased with height. Using several distributions of l^2 likely to be found in nature, Scorer had demonstrated the theoretical existence of waves very similar to those actually observed, i.e. with forward wind shear through a stable layer.

A contribution by Dr. Förchtgott of Prague was read by Mr. A. H. Yates. Dr. Förchtgott was an experienced glider pilot himself, and he had been able, with the help of the observations from a team of other glider pilots and ground observations, to present a reliable model of what was observed. With no inversion, rotatory movement, sometimes with a rotating cloud, could be observed under the peaks of the lee waves near the surface; at higher levels lenticular cloud was observed. With an inversion, a standing eddy occurred immediately to the lee of a ridge, which had the effect of enlarging the size of the hill and therefore the wave-length of the observed waves. The rotating clouds and the lenticular clouds were also observed to move very slowly with the wind but after a time to return rapidly to their original positions against the wind. Dr. Förchtgott had also devised a scheme whereby glider pilots could perform an adequate upper air sounding above standing waves; additional precautions were necessary because, owing to adiabatic changes, the temperature is warmer than elsewhere at the same level in a trough of the wave and colder at a crest.

In the general discussion that followed Mr. Wallington described a particular glider ascent in a standing wave over Camphill, Derbyshire, and showed how he had applied Scorer's theories to estimate the waves caused by each of the hills and valleys in the neighbourhood. Combining them all he had obtained an estimate of the wind flow which was within 20 per cent. of that actually observed. Prof. Gordon Manley confirmed the existence of Förchtgott's rotating clouds by reference to the Helm Bar produced in the lee of Cross Fell. Dr. Scorer gave some illustrations of how a standing wave can "change" the profile of a ridge so that the amplitudes of the lee waves are lessened although the wave-lengths are increased; he also showed how katabatic winds can accentuate lee waves and how a standing eddy can form on the flat top of a hill—this last was illustrated by a photograph of two wind socks flying in different directions at the same time. Mr. Rosenbrock, who was interested in windmill generation of electricity, described how an increase of 40–50 per cent. in wind strength could be gained by siting the windmill on the top of a ridge; theoretically the top of an isolated hill was not so good but there was little difference in practice because the isolated hill could take advantage of higher-level winds. Mr. Townsend, a forester, reported how most trees were blown down near the middle of hill and ridge slopes rather than near the top or bottom; but the evidence was not reliable because of the variability of trees and because they were likely to be smaller near the top of a hill.

At a meeting of the Society, held on January 26, 1955, Prof. P. A. Sheppard in the Chair, the following paper was read:—

Rossby, C.-G.—Chemical composition of precipitation as a function of atmospheric circulation patterns

Beginning in 1948, the monthly accumulations of precipitation at a network of 25 stations in Sweden were analysed for the concentration of the following ions: sodium (Na), potassium (K), calcium (Ca), ammonia (NH_3), nitrogen (N), nitric oxide (NO_3) and chlorine (Cl). From July 1951 the precipitation samples were analysed in addition for sulphur (S) and magnesium (Mg), and samples of the air at a number of the stations were also analysed for the different constituents. Since November 1954 the network has been increased to 41 stations extending to the other countries of Scandinavia.

Prof. Rossby discussed maps showing isopleths of the concentration of the different ions. The variation in the ratio of Cl : Na concentration with different circulation types was then illustrated; notable was the decrease from west to east with a strong westerly type and the high values of the ratio in a south-easterly type. A particularly interesting month was December 1953 when the air samples showed a marked maximum of Cl concentration in a south-easterly type, but the polar continental air mass, which produced northerly winds over Sweden, gave negligibly small amounts of Cl in precipitation.

Analysis of the annual totals, over the period of 4–5 yr. for the Na deposit (characteristic of maritime influence) and the S deposit (characteristic of continental influence) for three stations in western, central and southern Sweden, suggested a trend for increasing continental influence during this period. The mean circulation pattern for the year 1949 showed a definite westerly type over Sweden which was associated with high Na and low Cl concentration; on the other hand, 1952 showed an irregular pattern with no marked flow from any direction, and was associated with smaller Na values. The last map showed what Prof. Rossby considered to be the typical Cl concentration—the map indicated low concentrations over eastern Sweden and high values over central Russia.

Prof. Rossby said that this was in the nature of a preliminary report, but he considered the results were important enough to deserve further study and, he hoped, active research in other countries.

In the discussion speakers, whose work was connected with atmospheric-pollution research, referred to the useful data from a network of stations in this country, and co-operation was also promised by research workers in cloud physics.

INSTITUTE OF NAVIGATION

Accuracy of dead reckoning in the air

On Friday December 17, 1954, a paper on the "Accuracy of dead reckoning in the air" was read by Mr. C. S. Durst before the Institute of Navigation.

The purpose of the paper was to assess the magnitude of errors due to various causes in flying from one position to another, and also to show how these errors could be statistically combined, so producing the probable error in a dead-reckoning position when various navigational procedures are followed. The errors considered were those due to time keeping, to airspeed, to compass and to windage. In addition the effect of inaccurate position fixing was also taken into account.

The main emphasis was placed on errors due to windage, and tables were given showing the standard errors likely to arise from 24-hr. forecasts on routes of various lengths at various heights. In contrast the navigator having "found" a wind either by flying on three courses (at 60° to each other) or by measuring the drift of his aircraft between two successive fixes, may then use this found wind as a forecast for the next leg of his flight. The standard errors in such a procedure were calculated and exhibited.

Some typical examples were worked out to show how navigational and windage errors accumulated, (i) when an aircraft is flying over the ocean to intercept a convoy, (ii) when planning the necessary separation of contiguous air tracks at the same level, (iii) when planning homing equipment for an undeveloped route, and finally (iv) to answer the question when it is better to use a found wind than a forecast wind and *vice versa*.

In the course of a general discussion which followed, Wg Cmdr Anderson emphasized that one of the most accurate ways of obtaining found winds was by a three-drift method and that then the errors were very small.

Mr. J. B. Parker was anxious that casual errors in compass readings should be included as well as semi-systematic ones and that the navigator should have the errors presented as 50 per cent. circles of error. He stated that the total errors in dead reckoning appeared to be very considerably greater than the navigator was accustomed to expect.

Mr. H. E. Smith (British Overseas Airways Corporation) urged that every effort should be made to avoid the necessity of dead-reckoning navigation, rather than that the navigator be given more work in the air.

In winding up the meeting the Chairman, Sir Ralph Cochrane, also emphasized the ideal that dead reckoning should be abandoned and some black box should give the navigator his true position at any given moment.

LETTERS TO THE EDITOR

Glazed frost at Bwlchgwyn

After the memorable glazed frost of January 1940 I reported to the *Meteorological Magazine* the details of its occurrence at Bwlchgwyn*, and during the intervening fifteen years I have often wondered what exactly was the nature of the precipitation. A simpler case has recently occurred, insignificant compared with the 1940 phenomenon, yet I think it appropriate to describe it as it is the best case at Bwlchgwyn since that date; and glazed frost, in contrast to rime deposit, is rare even on the mountains.

On January 15, 1955, steady snowfall began at 0700 with a temperature of 24–25°F., and with the approach of a warm front this turned to drizzle at midday with a slow rise of surface temperature which, however, still remained well below freezing point. In a fresh SE. wind the drizzle turned to rain and coated everything—twigs, posts, wires, rushes, heather, and also the snow surface—with a coating of clear ice which reached ¼ in. thickness at the time of maximum development around sunset. The horizontal bars of wooden gates,

* *Met. Mag., London*, 75, 1940, p. 23.

but not metal wires, displayed icicles up to 3 in. long. The Stevenson screen at the Bwlchgwyn station (1,267 ft.) had its door completely frozen up with the deposit, and it took the best part of an hour to free all the instruments of it. On climbing, one broke through the ice crust, and ice plates, driven by the wind, tinkled their way down the mountain side perhaps for hundreds of yards. Lumps of snow adhering to the wool of the sheep were ice coated, and also tinkled as the animals moved. The pleasant sounds, produced by no other natural phenomenon, were impressive, and I particularly noted the sound of ice-laden rushes, bent down by the ice, rubbing in the wind on the ice layer on the snow.

At 1505 there was a brief period of heavy rain—quite ordinary rain which bore no evidence of supercooling. Immediately after this the low cloud broke, revealing an altostratus layer, becoming ruddy at sunset, and one was presented with the extraordinary spectacle of being surrounded everywhere by ice, with an air temperature of 30°, and a soft grey sky typical of a tropical maritime air stream on a mild December day. Of course, a few hundred feet higher up, that is just what was happening.

The glaze was appreciable at 1,000 ft., and the intensity increased rapidly with altitude up to 1,300 ft. After sunset there was a brief thaw, which was sufficient to melt the ice deposit before the ensuing snowfall.

S. E. ASHMORE

11 Percy Road, Wrexham, North Wales, January 23, 1955

Estimating temperature extremes

I was greatly interested in Mr. Lawrence's paper on "Estimation of the probabilities of given extreme minimum temperatures" in the *Meteorological Magazine* for January, as I have been working on possible extreme temperatures in the Wirral. His proposed frequency distribution seemed to be rather arduous to compute, so to compare its results with other distributions, I re-worked the Cambridge data in the Appendix using the normal frequency distribution and the same distribution adjusted for skewness, by the method given by Brooks and Carruthers*. This latter I have found the most suitable in the Wirral work. The skewness coefficient γ_1 was −0·28. The resultant probabilities, together with Lawrence's figures are given in Table I:—

TABLE I—EXPECTATION ONCE IN t YEARS

	Values of t					
	1·58	5	10	25	50	100
	degrees Fahrenheit					
$\sigma_1/\sigma_2 = 1·12$ ...	31·9	28·2	26·5	24·7	23·5	22·6
$\sigma_1/\sigma_2 = 1·15$ ...	31·8	28·2	26·5	24·9	23·8	23·0
Normal	31·6	28·0	26·6	25·2	24·2	23·4
Adjusted normal ...	31·8	28·0	26·5	24·9	23·8	22·8

Bearing in mind that the distribution is based on only 30 readings taken to the nearest 1°F. (standard error of observation 0·29°F.) of an element which may, or may not, be subject to secular change, it is clear that there is little to choose for accuracy between the four series. This being the case, the normal distribution wins the test on the grounds of simplicity of computation.

* BROOKS, C. E. P. and CARRUTHERS, N.; Handbook of statistical methods in meteorology. London, 1953, p. 114.

It may be argued that Cambridge is a bad example to take as it is nearly normal, but it is the only one with which Lawrence provides us, and other cases would need to be examined as they arose for evidence of skewness.

G. REYNOLDS

5 Raeburn Avenue, West Kirby, Cheshire, January 31, 1955

NOTES AND NEWS

Record of an unusually high rate of rainfall

By fitting a strip-chart mechanism, in place of the usual clock and drum, to a tilting-siphon rain recorder a much more open time scale may be secured. With this open scale details of variations of rainfall intensity which cannot be seen on the standard chart become apparent. Fig. 1 shows part of a trace obtained at Harrow on November 22, 1954, during the passage of a cold front, the last of a complex frontal system. The feature of interest is the abrupt change in intensity at 1724 from about 2 mm./hr. to over 100 mm./hr. (4 in./hr.). Unluckily, siphoning occurred during this intense rain; all we can say is that it persisted for at least 45 sec. and for not more than 75 sec. During the following 3 min. the intensity was about 20 mm./hr., and it is noticeable that the trace during this period is less smooth than either before or after.

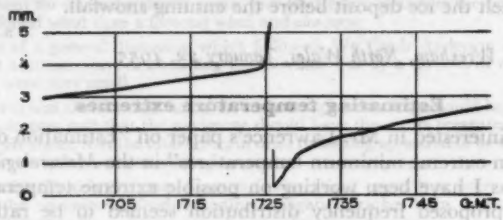

FIG. 1—RAINFALL RECORD, HARROW, NOVEMBER 22, 1954

Information about intense falls is of interest to many people, but the information is of limited value unless something is known about how large an area is at any one instant experiencing the heavy rain. It is planned to establish over an area of four square miles at Cardington, a close network of open-scale rain recorders with accurately synchronized clocks. A study of these open-scale synchronous records should lead to a much better understanding than we have at present of the structure of precipitating clouds.

R. FRITH

REVIEW

Snow crystals: natural and artificial. By U. Nakaya. 10½ in. × 7⅞ in., pp. xiv+510, *Illus.*, Harvard University Press (London: Geoffrey Cumberlege), 1954. Price: 80*s.* net.

It is not often that the research subject of the professional scientist is equally worthy of study for the sake of its beauty. In this respect the author of this book is to be congratulated, not only on his own good fortune but also for the aesthetic appeal of the 1,400 microphotographs of snow crystals which adorn this volume. Comparison with Bentley's collection of photographs is inevitable.

For some the pictorial appeal of Bentley's white photographs on their black background will be greater than that of the present photographs, for which some oblique illumination was used in order to emphasize the topography of the crystal surfaces. The different photographic technique employed by the present author is indicative of the greater emphasis on scientific research. In this connexion it should be mentioned that every photograph is accompanied by an indication of the magnification.

This book gives an account of 12 years' research by Prof. Nakaya and his collaborators. The first half deals with natural snow crystals observed at Sapporo and on Mount Tokachi in Japan. Chapter 1—the longest chapter in this part of the book—describes in detail and with many illustrations the various types of snow crystal found. Although most of the plates show regular crystals the author emphasizes that irregular or malformed crystals are just as frequent. Chapter 2 classifies the snow crystals observed by the author and gives an indication of the frequency of occurrence of the various types and of their dimensions. The third and last chapter of this part deals with the physical properties of snow crystals—the form, mass, and terminal velocity of individual crystals, the relationship between these parameters and the electrical charge on individual crystals.

The second part of the book deals with artificial snow. After a short chapter on artificial frost crystals formed on a solid surface, Chapter 5 describes the technique for the production of artificial snow crystals. These crystals were developed from "germs" which formed upon a filament of silk or of rabbit hair suspended in a chamber in which the temperature and humidity could be controlled. The humidity was controlled by the use of a dish of heated water in the base of the chamber, and the author uses the water temperature as a measure of the humidity. The importance of the rate of growth in determining the form of the crystal is stressed by the author. Some crystals were grown in less than an hour, others required more than 24 hr. A feature of this chapter is the wealth of experimental detail. Chapter 6—the longest in the book—is devoted to a description of the many different kinds of crystal the author has made in the laboratory and of the conditions in which they were made. It is profusely illustrated. Chapter 7 contains a number of pairs of photographs of similar crystals—one natural and one artificial—covering a variety of crystal types. For many of these pairs the text contains a detailed description of the physical conditions in which the artificial crystal was developed. Finally there is a short chapter on recent research.

Most of the contents of the book have been published in thirteen separate papers (but, presumably, not most of the plates) and the book itself has the style rather of a scientific paper than a textbook.

The painstaking work of the author and his associates and the careful preparation of the manuscript have been matched by the work of the publisher. The reviewer believes that any one who is interested in this field of research will consider the book good value for money. A Japanese edition of this book was destroyed while in the press by bombing during the war. The fact that publication of this English edition was made possible by assistance from both Hokkaido University and various American authorities is a happy reminder of the international nature of scientific research.

A. C. BEST

HONOURS

Dr. J. M. Stagg, C.B., O.B.E., Principal Deputy Director, Meteorological Office, has been awarded a Gauss-Weber medal by the Academy of Science, Göttingen, "for his researches in geomagnetism especially his discussion of the Fort Rae Polar Year (1932–3) data and the investigations arising therefrom, so furthering the aims which Gauss and Weber envisaged when they set up the Magnetic Union in 1831".

Dr. Stagg received the medal on February 19, 1955 at a ceremony in the Union Hall, Göttingen, arranged by the University and the Academy of Science, Göttingen, to commemorate the hundredth anniversary of the death of Carl Frederick Gauss. The five other recipients of the medal were continental scientists distinguished in the fields in which Gauss and his contemporary Weber had made fundamental contributions: astronomy, astrophysics, mathematics and communications. Sir Geoffrey Taylor represented the Royal Society at the ceremony; the main ovation in honour of Gauss and Weber was made by Dr. Richard Courant of New York.

It was announced in the London Gazette of March 1, 1955 that Mr. B. D. Hunt, Scientific Assistant at Bovingdon, has been awarded the Polar Medal for good services as a member of the Falkland Islands Dependencies Survey in Antarctic expeditions during the years 1949–54. Mr. Hunt served as Meteorological Assistant at Hope Bay in 1952.

METEOROLOGICAL OFFICE NEWS

Retirement.—Mr. A. G. W. Howard, Experimental Officer, retired on January 31, 1955, after 49 years' service. He joined the Office in September 1905 and served in the Forecast Division until 1917, when he was transferred to the Marine Division. From 1923 to 1945 he served in the Climatological Branch, and whilst the Branch was at Stroud during the Second World War Mr. Howard took an active part in Civil Defence work. From 1945 until his retirement he served at Kew Observatory.

Academic success.—We offer our congratulations to Mr. R. C. Smith, Scientific Officer, who has been admitted to the degree of Ph.D. in Meteorology in the University of London.

WEATHER OF FEBRUARY 1955

Pressure was again much above normal north-west of the British Isles, an anticyclone (1022 mb. or above) over Greenland being more prominent than the Atlantic high (represented by 1017 mb. at Madeira) on the mean map. Pressure was lowest (1005 mb.) in the middle Baltic and near the Norwegian weather station M. Anomalies ranged from +14 mb. over west Greenland to −13 mb. over central Europe.

Mean temperature was below normal over northern Europe (greatest anomaly −4°C. in Denmark and at Stornoway) and over Iceland and Greenland. The Mediterranean and the southern half of Europe was warmer than usual, anomalies of +3°C. occurring in central Italy and +4°C. in Tripolitania.

There was excessive rainfall, reaching two to three times the normal amount in a band across central Europe from Brittany to the lower Danube basin. Under half the normal amounts of equivalent rainfall were measured in east Greenland, south Iceland and in parts of the central and eastern Mediterranean.

In the British Isles it was rather mild for the first week especially in the south, but for the rest of the month it was cold with temperature everywhere below the average and with considerable snowfall at times. A notable feature of the month was the extremely low temperature recorded at some places. There was more than average sunshine nearly everywhere except during the last

week in England and Wales, but during this week there was more than twice the average for the month in parts of Scotland.

During the first few days pressure was low to the north-west of the country and depressions from the Atlantic moved eastward across Wales and the southern half of England bringing considerable rain to the south-west; parts of Devon and Cornwall had more than 2½ in. of rain during the first week, but there were no large falls elsewhere. Weather was mild with sunny periods for a time, but cold northerly winds, accompanied by slight snow showers spread over Scotland and parts of northern England during the latter part of the week; nevertheless, at many places on the south coast, temperature rose to 57°F. on the 7th. A marked change took place at the beginning of the second week when a ridge of high pressure developed south-eastwards from an anticyclone over Greenland, and during the 8th and 9th cold air accompanied by local thunder spread south over the whole country causing temperatures to fall as much as 5–10°F. Generally sunny weather followed but with snow showers, and these were frequent and often prolonged in north and east Scotland and over much of eastern England. Temperatures continued to fall progressively lower till by the end of the third week they were rising little above freezing point during the day. There were extensive outbreaks of snow on the 14th, and it lay from 1 to 3 in. deep on many roads in the east Midlands and up to 6 in. deep in parts of Lincolnshire that afternoon. On the 17th, a polar depression, accompanied by local thunder, moved south in the northerly stream and by the evening snow lay up to 6 in. deep in many parts of north-east England and the Midlands. The strong northerly winds, reaching gale force at times, caused serious snow-drifts in Scotland, and many farms and villages were isolated and had to be supplied by air. The winds moderated on the 18th as a weak low-pressure system settled over the country, and that night there were heavy falls of snow in Scotland, reported to be the most severe of the century. Among the greater depths of undrifted snow reported were 23½ in. at Glenmore, Inverness-shire, 18 in. at Glenrossal, Sutherland, and 12 in. at Glenshee, Perth, at Drummuir, Banffshire, and at Buxton, Derbyshire. Substantial falls occurred in Lancashire and Norfolk also; drifts up to 5 ft. were reported from Blackpool and Wells-on-Sea, Norfolk, was isolated by drifts. In five days during this period the Royal Air Force dropped 38 tons of hay to cattle marooned by the snow in Scotland. Very low temperatures were experienced as a consequence of the decrease in gradient and snow-cover; Northolt registered a ground temperature of −3°F. and Kew 2°F., this latter the lowest there for 30 yr., on the morning of the 20th. A temporary invasion of warmer air gave further rain and snow in the south-west, accompanied by thunderstorms in the western English Channel, but even colder weather followed over Scotland, and at Braemar in the Grampians screen temperature fell to −13°F. on the morning of the 23rd, the lowest in Great Britain since 1895. Throughout the last week of the month easterly winds prevailed over most of the country with low pressure over the Bay of Biscay and slow-moving fronts lying along the English Channel. Southern England had frequent outbreaks of rain or snow, and in particular there were substantial falls in the south-west on the 23rd; snow fell continuously from 0400 to 2000 and most roads in Cornwall were snowbound. From time to time the snow spread as far north as Scotland, but mostly western Scotland, Northern Ireland and north-west England had bright cold weather, particularly in the Hebrides where Stornoway's sunshine reached the record total of 96 hr. during the month, the previous highest for February there being 91 hr. in 1886. Holyhead had 113 hr., its previous highest being 108 hr. in 1930. On the morning of the 27th screen temperature fell to 20°F. or below in many places in the north but the lowest screen temperature for this month in England and Wales was −1°F. at Houghall, Durham, on the 20th. Rain from the Atlantic was by now affecting Northern Ireland and western Scotland, and on the last day of the month milder weather with a good deal of rain spread across Ireland and much of Scotland accompanied by southerly gales with mean wind speeds 40–50 kt. The rain was exceptionally heavy in west Scotland. Among the heaviest falls reported in 24 hr. on the 28th were 5·30 in. at Ardrishaig, Argyllshire, 5·75 in. at Inverailort, Inverness-shire, and 5·04 in. at Glenbranter, Argyllshire. The 28th however was very sunny over east and south-east England with over 9 hr. sunshine in many places, and although temperatures in the morning had been as low as 15–20°F. below freezing point in many places, they rose to 35–40°F. in the afternoon.

The general character of the weather is shown by the following provisional figures:—

	AIR TEMPERATURE			RAINFALL		SUNSHINE
	Highest	Lowest	Difference from average daily mean	Percentage of average	No. of days difference from average	Percentage of average
	°F.	°F.	°F.	%		%
England and Wales ...	59	−1	−4·9	102	+2	122
Scotland	55	−13	−5·9	87	0	142
Northern Ireland ...	55	4	−6·1	120	0	117

RAINFALL OF FEBRUARY 1955

Great Britain and Northern Ireland

County	Station	In.	Per cent. of Av.	County	Station	In.	Per cent. of Av.
London	Camden Square ...	1·61	96	*Glam.*	Cardiff, Penylan ...	1·96	67
Kent	Dover	2·10	109	*Pemb.*	Tenby	2·64	91
„	Edenbridge, Falconhurst	2·15	97	*Radnor*	Tyrmynydd	3·80	72
Sussex	Compton, Compton Ho.	2·40	91	*Mont.*	Lake Vyrnwy	3·26	71
„	Worthing, Beach Ho. Pk.	1·92	97	*Mer.*	Blaenau Festiniog ...	4·70	57
Hants.	St. Catherine's L'thouse	1·98	98	„	Aberdovey	2·05	89
„	Southampton (East Pk.)	2·05	89	*Carn.*	Llandudno	1·80	92
„	South Farnborough ...	1·50	80	*Angl.*	Llanerchymedd ...	2·57	102
Herts.	Harpenden, Rothamsted	2·24	117	*I. Man*	Douglas, Borough Cem.	4·00	125
Bucks.	Slough, Upton	1·52	99	*Wigtown*	Newton Stewart ...	3·22	86
Oxford	Oxford, Radcliffe ...	1·42	87	*Dumf.*	Dumfries, Crichton R.I.	2·00	61
N'hants.	Wellingboro' Swanspool	1·65	102	„	Eskdalemuir Obsy. ...	3·41	69
Essex	Southend, W. W. ...	1·29	95	*Roxb.*	Crailing...	2·23	121
„	Felixstowe	1·88	149	*Peebles*	Stobo Castle	1·92	70
Suffolk	Lowestoft Sec. School ...	1·75	125	*Berwick*	Marchmont House ...	2·60	125
„	Bury St. Ed., Westley H.	2·05	137	*E. Loth.*	North Berwick Gas Wks.	1·52	97
Norfolk	Sandringham Ho. Gdns.	2·62	160	*Midl'n.*	Edinburgh, Blackf'd. H.	1·43	86
Wilts.	Aldbourne	1·69	74	*Lanark*	Hamilton W. W., T'nhill	2·64	91
Dorset	Creech Grange... ...	2·33	82	*Ayr*	Colmonell, Knockdolian	...	...
„	Beaminster, East St. ...	3·04	100	„	Glen Afton, Ayr San. ...	2·11	48
Devon	Teignmouth, Den Gdns.	2·61	98	*Renfrew*	Greenock, Prospect Hill	3·92	74
„	Ilfracombe	3·20	116	*Bute*	Rothesay, Ardencraig ...	3·03	76
„	Princetown	5·96	79	*Argyll*	Morven, Drimnin ...	4·81	91
Cornwall	Bude, School House ...	2·67	107	„	Poltalloch	3·63	84
„	Penzance	5·16	154	„	Inveraray Castle ...	2·96	44
„	St. Austell	5·11	133	„	Islay, Eallabus	3·70	86
„	Scilly, Tresco Abbey ...	5·18	186	„	Tiree	3·02	88
Somerset	Taunton	2·73	131	*Kinross*	Loch Leven Sluice ...	3·61	128
Glos.	Cirencester	1·65	73	*Fife*	Leuchars Airfield ...	1·80	105
Salop	Church Stretton ...	2·32	99	*Perth*	Loch Dhu	4·79	64
„	Shrewsbury, Monkmore	1·69	108	„	Crieff, Strathearn Hyd.	1·59	45
Worcs.	Malvern, Free Library...	1·71	95	„	Pitlochry, Fincastle ...	2·19	74
Warwick	Birmingham, Edgbaston	2·11	113	*Angus*	Montrose, Sunnyside ...	2·57	140
Leics.	Thornton Reservoir ...	1·95	117	*Aberd.*	Braemar	3·65	128
Lincs.	Boston, Skirbeck ...	2·86	196	„	Dyce, Craibstone ...	2·82	125
„	Skegness, Marine Gdns.	2·21	144	„	New Deer School House	2·96	139
Notts.	Mansfield, Carr Bank ...	2·19	113	*Moray*	Gordon Castle	2·00	104
Derby	Buxton, Terrace Slopes	4·65	124	*Nairn*	Nairn, Achareidh ...	1·92	119
Ches.	Bidston Observatory ...	1·84	109	*Inverness*	Loch Ness, Garthbeg ...	...	...
„	Manchester, Ringway...	1·59	83	„	Glenquoich	5·49	53
Lancs.	Stonyhurst College ...	1·72	51	„	Fort William, Teviot ...	4·24	57
„	Squires Gate	2·34	110	„	Skye, Broadford ...	3·77	58
Yorks.	Wakefield, Clarence Pk.	2·75	161	„	Skye, Duntuilm ...	3·88	84
„	Hull, Pearson Park ...	2·07	125	*R. & C.*	Tain, Mayfield... ...	2·39	104
„	Felixkirk, Mt. St. John...	2·26	134	„	Inverbroom, Glackour...	4·07	80
„	York Museum	1·71	113	„	Achnashellach	5·17	75
„	Scarborough	1·87	111	*Suth.*	Lochinver, Bank Ho. ...	3·36	84
„	Middlesbrough... ...	1·63	125	*Caith.*	Wick Airfield	3·13	138
„	Baldersdale, Hury Res.	1·59	54	*Shetland*	Lerwick Observatory ...	3·02	96
Nor'd.	Newcastle, Leazes Pk....	2·74	179	*Ferm.*	Crom Castle	3·46	118
„	Bellingham, High Green	3·23	127	*Armagh*	Armagh Observatory ...	3·55	160
„	Lilburn Tower Gdns. ...	3·45	173	*Down*	Seaforde	3·58	117
Cumb.	Geltsdale	2·10	81	*Antrim*	Aldergrove Airfield ...	3·24	134
„	Keswick, High Hill ...	1·69	34	„	Ballymena, Harryville...	3·83	118
„	Ravenglass, The Grove	1·02	33	*L'derry*	Garvagh, Moneydig ...	4·07	139
Mon.	A'gavenny, Plâs Derwen	2·38	68	„	Londonderry, Creggan	3·26	102
Glam.	Ystalyfera, Wern House	3·34	64	*Tyrone*	Omagh, Edenfel ...	2·92	98

Printed in Great Britain under the authority of Her Majesty's Stationery Office
By Geo. Gibbons Ltd., Leicester

Wt·34. K16.